

WATER RESOURCES DEVELOPMENT PROJECT

**SAXONVILLE
LOCAL PROTECTION**

**SUDBURY RIVER
MERRIMACK RIVER BASIN**

FRAMINGHAM, MASSACHUSETTS

**DESIGN MEMORANDUM NO. 1
HYDROLOGIC ANALYSIS**



**DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.**

DECEMBER 1972

20

DAEN-CWE-B (NEDED-W, 12 Dec 72) 1st Ind
SUBJECT: Saxonville Local Protection Project, Sudbury River, Massachusetts,
Design Memorandum No. 1 - Hydrologic Analysis

DA, Office of the Chief of Engineers, Washington, D.C. 20314 23 February 1973

TO: Division Engineer, New England, ATTN: NEDED-W

1. Approved, subject to the comments furnished in the following paragraphs.

2. Paragraph 18 and Table 1-X. Guidance for channel riprap design is contained in paragraph 14 of EM 1110-2-1601 and in ETL 1110-2-120. The use of maximum depths of flow and friction slopes, as determined from backwater studies to develop profiles for height of protection, is unsatisfactory for riprap design. The computed values of D_{50} minimums become smaller as more conservative friction factors are used. Conservatism for riprap design is obtained by assuming friction factors on the smooth limit side in order to obtain the shallowest depth and maximum velocity feasible. Further discussion on this aspect is contained in paragraph 3d of ETL 1110-2-120. This matter should be studied further and the results reported in an ensuing design memorandum.

3. Future design memoranda should be submitted to the addressee indicated in paragraph 20a of ER 1110-2-1150.

FOR THE CHIEF OF ENGINEERS:

1 Incl
wd

W. D. Phillips
for JOSEPH M. CALDWELL
Chief, Engineering Division
Directorate of Civil Works



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-W

12 December 1972

SUBJECT: Saxonville Local Protection Project, Sudbury River,
Massachusetts, Design Memorandum No. 1 - Hydrologic
Analysis

HQDA (DAEN-CWP-E)
WASH DC 20314

1. In accordance with ER 1110-2-1150, there is submitted for review and approval Design Memorandum No. 1 - Hydrologic Analysis, Saxonville Local Protection Project, Sudbury River, Massachusetts.

2. The plan of development is essentially the same as that presented in the Saxonville Survey Report, dated February 1965. However, the Standard Project Flood discharge at Saxonville has been revised upward as a result of the detailed hydrologic studies reported in this memorandum. Consequently, this increased design discharge will require higher flood control works than those proposed in the Survey Report.

FOR THE DIVISION ENGINEER:

A handwritten signature in cursive script, appearing to read "John Wm. Leslie".

JOHN WM. LESLIE
Chief, Engineering Division

1 Incl (7 cys)
as

WATER RESOURCES DEVELOPMENT PROJECT

SAXONVILLE LOCAL PROTECTION PROJECT
SUDBURY RIVER, MASSACHUSETTS

DESIGN MEMORANDA INDEX

<u>Number</u>	<u>Title</u>	<u>Anticipated Submission Date</u>	<u>Date Submitted</u>	<u>Date Approved</u>
1	Hydrologic Analysis		12 Dec 1972	
2	General Design - Phase I	March 1973		
	General Design - Phase II	January 1974		
3	Concrete Materials	February 1974		
4	Embankments & Foundations	February 1974		
5	Design of Structures	April 1974		

SAXONVILLE LOCAL PROTECTION PROJECT
SUDBURY RIVER
MASSACHUSETTS

DESIGN MEMORANDUM NO. 1

HYDROLOGIC ANALYSIS

<u>Paragraph</u>	<u>Subject</u>	<u>Page</u>
1	INTRODUCTION	
a	Purpose	1
b	Project authorization	1
c	Project description	1
d	Revised Standard Project Flood	2
	PART I - HYDROLOGY	
2	DESCRIPTION OF SUDBURY RIVER WATERSHED	
a	General	2
b	Existing reservoirs	2
3	CLIMATOLOGY	
a	General	3
b	Temperature	3
c	Precipitation	5
d	Snowfall	5
e	Snow cover	5
f	Storms	5
4	RUNOFF AND STREAMFLOW DATA	
a	Discharge records	10
b	Runoff	10
5	HISTORY OF FLOODS	
a	General	10
b	Floods of record	13

<u>Paragraph</u>	<u>Subject</u>	<u>Page</u>
6	FLOOD FREQUENCY ANALYSIS	13
7	ANALYSIS OF FLOOD OF AUGUST 1955	13
8	UNIT HYDROGRAPH DEVELOPMENT	16
9	STANDARD PROJECT FLOOD DEVELOPMENT	
a	General	16
b	Standard Project Storm	17
c	Inflow hydrograph development	17
d	Standard Project Flood routing	18
10	INTERIOR DRAINAGE HYDROLOGY	
a	General	18
b	Description of area	19
c	Unit hydrographs	19
d	Design storm	19
e	Runoff hydrographs	19
f	Seepage	19
g	Ponding	20
h	Pumping station	20
i	Gravity outfall	21
j	Interceptor drain	21
	PART II - HYDRAULIC ANALYSIS	
11	GENERAL	21
12	WATER SURFACE PROFILES	
a	General	22
b	Manning's "n"	22
c	Transition losses	22
d	Cross-section data	22
e	Discharge rating curves	23
13	EFFECT OF PROJECT ON FLOOD HEIGHTS	24
14	VELOCITIES	24
15	FLOW CLASSIFICATION	24

<u>Paragraph</u>	<u>Subject</u>	<u>Page</u>
16	HYDRAULICS OF BRIDGES	24
17	FREEBOARD DESIGN	25
18	RIPRAP DESIGN	25

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
1-I	Pertinent Data on Reservoirs and Dams in the Sudbury River Watershed	4
1-II	Monthly Temperature Record	6
1-III	Monthly Precipitation Record	7
1-IV	Monthly Snowfall Record	8
1-V	Water Equivalents of Snow Cover - Blackstone River Basin	9
1-VI	Concord River Watershed Streamflow Records Through Water Year 1970	11
1-VII	Monthly Runoff	12
1-VIII	Pertinent Discharge-Frequency Data	14
1-IX	Standard Project Storm Rainfall	17
1-X	Hydraulic Data for Channel Riprap Design	26

LIST OF PLATES

<u>Plate</u>	<u>Title</u>
1-1	Sudbury River Watershed Map
1-2	Discharge-Frequency Curves
1-3	Flood of August 1955
1-4	" " " "
1-5	6-Hour Unit Hydrographs
1-6	Standard Project Flood
1-7	" " "
1-8	Interior Drainage
1-9	Plan and Profile
1-10	Sudbury River Rating Curves
1-11	Spillway Rating Curves - Saxonville Dam
1-12-1-14	Daily Flow Hydrographs - Assabet River at Maynard, Massachusetts

SAXONVILLE LOCAL PROTECTION PROJECT

SUDBURY RIVER
MERRIMACK RIVER BASIN
MASSACHUSETTS

DESIGN MEMORANDUM NO. 1

1. INTRODUCTION

a. Purpose. This memorandum presents the hydrology and hydraulics pertinent to the design of the Saxonville Local Protection Project on the Sudbury River through the village of Saxonville in the town of Framingham, Massachusetts. The Sudbury River is a tributary of the Concord River, which flows into the Merrimack River at Lowell, Massachusetts. Part I, Hydrology, includes sections on climatology, streamflow, analysis of flood development, derivation of the Standard Project Flood and criteria for interior drainage. Part II, Hydraulics, presents hydraulics of the dam and river channel, including water surface profiles, discharge ratings, velocities, riprap criteria and freeboard design.

b. Project authorization. The Saxonville Local Protection Project was recommended in "Interim Report on Review of Survey, Saxonville Local Protection," dated 26 February 1965, and submitted in Senate Document No. 61, dated 7 October 1965. The project was authorized by the Flood Control Act of 1966, Public Law 89-789, dated 7 November 1966.

c. Project description. The project at Saxonville will consist of protective works along the Sudbury River from the Saxonville Pond dam at Central Street to the Danforth Street bridge, a distance of about 3,800 feet. The project will involve construction of about 2,900 feet of earth dikes, 750 feet of concrete floodwalls, a vehicular floodgate, a railroad closure and a pumping station for interior drainage. A section of the river channel between the New York Central Railroad bridge and Danforth Street bridge will be relocated and straightened for a distance of about 1,200 feet. This improved channel will have a trapezoidal section with a 60-foot bottom width. A plan of the Saxonville project is shown on plate 9.

d. Revised Standard Project Flood. More detailed hydrologic design study has resulted in a significant increase in the Standard Project Flood (SPF) over that reported in the 1965 Survey Report. The SPF discharge developed during preauthorization studies was determined using a rainfall-runoff relationship at Saxonville, based on the experienced August 1955 rainfall and flood discharge. In the 1965 analysis, it was assumed that the effect of a system of upstream reservoirs on the SPF would be somewhat proportional to their effect on the 1955 flood and that a more comprehensive reservoir system analysis would be made in postauthorization studies. This more detailed study was performed and has resulted in an increase in the SPF discharge at Saxonville. Discussion of the reservoir system study and the desired SPF is presented for review in subsequent sections of this design memorandum.

PART I - HYDROLOGY

2. DESCRIPTION OF SUDBURY RIVER WATERSHED

a. General. The Sudbury River, draining a fan-shaped watershed of 166 square miles, originates in Cedar Swamp Pond in the town of Westborough, Massachusetts. The river meanders first, generally eastward, then northward, about 30 miles to its confluence with the Assabet River to form the Concord River, a principal tributary of the Merrimack River. The topography of the basin is generally rolling with maximum perimeter elevations ranging from 500 to 600 feet above mean sea level (msl). The slope of the river varies from 11 feet per mile in the relatively steep upper reaches to about one foot per mile in the lower reaches. A map of the watershed is shown on plate 1-1.

The limits of the study area for hydrologic evaluation included the entire 106 square mile drainage area above the Danforth Street bridge, just below the Saxonville section of the town of Framingham. A riverine hydraulic analysis was performed from the large swamp below Danforth Street bridge upstream to Saxonville Pond, a distance of approximately 4,500 feet. This very flat reach of the Sudbury River has overtopped its banks several times in the past, inundating a large area of Saxonville, causing considerable damage.

b. Existing reservoirs. A complex system of reservoirs exists on the Sudbury River and its tributaries above the village of Saxonville. Sudbury Reservoir and Framingham Reservoir No. 3, located

on Stony Brook, and Reservoirs Nos. 1 and 2 on the Sudbury River, are owned and operated by the Metropolitan District Commission of the Commonwealth of Massachusetts and are part of the large regional water supply system that serves the greater Boston area. Ashland, Hopkinton and Whitehall reservoirs, all located on tributaries of the Sudbury River in the southern portion of the basin, are maintained for recreation by the Division of Forest and Parks, Department of Natural Resources, Commonwealth of Massachusetts. Saxonville Pond, situated just above the area of proposed protection, is maintained and operated by the Roxbury Carpet Company of Saxonville as a source of industrial water supply. Approximately 3,000 feet downstream of Saxonville Pond dam the river is joined by Cochituate Brook, the only tributary stream of any significance in the local protection area. The major portion of the drainage area of this stream is controlled by Lake Cochituate, which is also maintained for recreation by the above referenced Division of Forest and Parks.

Although there is little storage in the entire system specifically allocated for flood control, the reservoirs, as a result of their operation for water supply, have in the past provided a large modifying effect on floods. In addition, surcharge storage in the reservoirs and extensive natural-valley and swamp storage along the river also account for some reduction in flood peaks.

Pertinent data on all of the reservoirs are listed in table 1-I, and the reservoirs are shown graphically on plate 1-1.

3. CLIMATOLOGY

a. General. The climate of the Sudbury River watershed is characterized by variable weather, with frequent but usually short periods of precipitation. The basin is exposed to intense rainfall due to coastal storms of tropical origin that travel up the Atlantic seaboard or storms of an extratropical nature, often called "northeasters." The watershed also lies in the path of the "prevailing westerlies" and with air masses moving predominantly from the interior of the country, this west to southwest airflow brings the hot, dry weather which is responsible for occasional summer droughts.

b. Temperature. The average annual temperature at Framingham for 87 years of record is 49.2° Fahrenheit (F.). Average monthly

TABLE 1-I

PERTINENT DATA ON RESERVOIRS AND DAMS IN THE SUDBURY RIVER WATERSHED

<u>Name</u>	<u>Drainage Area (sq. mi.)</u>	<u>Surface Area (acres)</u>	<u>Capacity (ac-ft)</u>	<u>Spillway Length (feet)</u>	<u>Spillway Crest Elevation (ft msl)</u>	<u>Top of Flashboards (ft msl)</u>	<u>Top of Dam Elevation (ft msl)</u>
Ashland	6.43	169	4,345	30	218.58	219.56	225.35
Hopkinton	5.86	193	4,665	30	298.35	299.35	305.35
Whitehall	4.35	601	3,855	--	--	--	334.25*
Sudbury	22.28	1,292	22,249	300	253.35	254.51	260.35
Framingham #1	74.66	154	954	168.25	161.95	163.62	171.15
" #2	45.14	134	1,726	184.38	170.22	171.47	178.18
" #3	27.68	250	3,680	100.25	179.64	180.85	185.67
Saxonville	86	30±	--	181.7	144.8	146.0±	148 left abut. 150 right abut.
L. Cochituate	17.58	730	6,433	63	138.71	138.75	142.71

* Overflow elevation of roadway on top of dam.

temperatures vary widely throughout the year from about 72° F. in July to about 26° F. in January. Temperature extremes range from occasional recorded highs in excess of 100° in July and August to infrequent lows below -20° in January and February. Freezing temperatures can be expected from November through March. The mean, maximum, and minimum temperatures are shown in table 1-II.

c. Precipitation. The average annual precipitation at Framingham for 96 years of record is about 44 inches, distributed rather uniformly throughout the year. The maximum and minimum annual precipitation totals are nearly 60 inches and 29 inches, respectively. During the month of August 1955, a total rainfall of 15.69 inches established the record monthly maximum. During the period 17 to 21 August, over 12 inches were recorded and caused the flood of record at Saxonville. Table 1-III summarizes the precipitation records for Framingham.

d. Snowfall. The average annual snowfall at Framingham is approximately 51 inches. Snowfall usually occurs over the 6-month period from November through April with the amounts for the months of December, January and February accounting for over 70 percent of the annual total. Monthly and annual average snowfall for 43 years of record at Framingham are tabulated in table 1-IV.

e. Snow cover. Water content of the snow cover in the region reaches a maximum depth ranging from 3 to 6 inches about the first of March. A summary of snow survey data collected by this office in the adjacent Blackstone River basin since 1957 is shown in table 1-V.

f. Storms. Storms of three different types occur in the watershed, namely, cyclonic storms of continental origin, coastal storms and thunderstorms. Cyclonic storms have occurred during all seasons of the year; however, winter storms are more generally associated with this type of disturbance. These storms are usually of greater areal extent but do not produce such intense precipitation centers as storms of the other two types. Thunderstorms are usually of the convective type and are therefore generally limited to summertime occurrences. These storms are usually characterized by intense rainfall centers of limited areal extent which are often conducive to tributary flooding. The coastal storms consist of two types: (a) the extratropical maritime storms which originate and

TABLE 1-II

MONTHLY TEMPERATURE RECORD
(In Degrees Fahrenheit)

Framingham, Massachusetts Elevation 170 feet msl
Observed by Metropolitan District Water Commission

87 Years of Record Through 1971

<u>Month</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	26.3	72	-24
February	26.8	66	-21
March	36.2	85	- 3
April	47.3	93	10
May	58.3	96	25
June	67.2	100	35
July	72.3	102	42
August	69.9	104	34
September	62.9	95	27
October	52.4	91	16
November	41.0	83	6
December	29.9	71	-16
ANNUAL	49.2	104	-24

TABLE 1-III

MONTHLY PRECIPITATION RECORD

Framingham, Massachusetts Elevation 170 feet msl
Observed by Metropolitan District Water Commission

96 Years of Record Through 1971

<u>Month</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	3.86	9.67	.75
February	3.77	8.82	.26
March	4.16	9.61	.04
April	3.65	8.78	.85
May	3.24	7.01	.72
June	3.28	9.33	.38
July	3.47	11.80	.73
August	3.62	15.69	.54
September	3.53	10.65	.18
October	3.29	10.26	.10
November	4.04	7.94	.89
December	3.91	10.87	.92
ANNUAL	43.82	59.94	28.96

TABLE 1-IV

MONTHLY SNOWFALL RECORD
(Average Depth in Inches)

Framingham, Massachusetts Elevation 170 feet ms1
Observed by Metropolitan District Water Commission

43 Years of Record Through 1971

<u>Month</u>	<u>Snowfall</u>
January	13.1
February	14.0
March	9.9
April	1.8
May	Trace
June	-
July	-
August	-
September	-
October	Trace
November	2.8
December	9.6
ANNUAL	51.2

TABLE 1-V
WATER EQUIVALENTS OF SNOW COVER
BLACKSTONE RIVER BASIN
1957-1971
(Inches)

<u>Date</u>	<u>Minimum</u>	<u>Mean</u>	<u>Maximum</u>
1 FEB	0	1.85	3.9
15 FEB	0.2	2.55	5.2
1 MAR	0.2	2.75	6.0
15 MAR	0	2.25	5.0
1 APR	0	0.7	3.3
15 APR	0	0	0.7

move northward along the eastern seaboard, and (b) the storms of tropical origin, many of which attain hurricane magnitude. Of the two, the tropical hurricanes constitute the greater potential for flood producing precipitation. They occur most often between the months of July and October.

Five recent flood producing storms in the Sudbury River watershed occurred in March 1936, July 1938, September 1954, August 1955 and March 1968. Floods in March 1936 and 1968 were caused by a combination of rainfall and snowmelt, whereas the other four were the result of only high volume intense rainfall. Record rainfall from hurricane "Diane" produced the flood of record in the Sudbury River basin, and it occurred after the soil conditions had been saturated from the preceding hurricane "Connie".

Storm totals in the vicinity of the Sudbury watershed for the five storms were as follows:

March 1936	4.0 inches
July 1938	8.0 "
September 1954	8.5 "
August 1955	12.5 "
March 1968	4.9 "

4. RUNOFF AND STREAMFLOW DATA

a. Discharge records. Since 1875, runoff has been recorded at three locations in the Concord River watershed for varying periods of time. A summary of the data from these stations reported by the U.S. Geological Survey is listed in table 1-VI.

b. Runoff. A summary of monthly runoff for the Sudbury River at Framingham, the Assabet River at Maynard, and for the Concord River below River Meadow Brook at Lowell, Massachusetts is presented in table 1-VII. The runoff data for the Sudbury River were furnished by the Metropolitan District Commission and adjusted for change in reservoir contents and diversions from the basin.

Daily flow hydrographs for the Assabet River at Maynard are shown on plates 1-12 through 1-14.

5. HISTORY OF FLOODS

a. General. As noted in Section 3, "Climatology," outstanding floods may occur during any season of the year. Early spring rains accompanied by melting snow resulted in the floods of March 1936

TABLE 1-VI
CONCORD RIVER WATERSHED
STREAMFLOW RECORDS

<u>Location of Gaging Station</u>	<u>Drainage Area (sq. mi.)</u>	<u>Period of Record</u>	<u>Mean Flow (cfs)</u>	<u>Instantaneous Maximum Flow (cfs)</u>	<u>Daily Minimum Flow (cfs)</u>
Assabet River at Maynard, Mass.	116	1941-1970	177	4,250 ⁽²⁾	0.2
Sudbury River at Framingham Center, Mass.	75.2	1875-1970	113 ⁽¹⁾	-	-
Concord River below River Meadow Brook at Lowell, Mass.	405	1936-1970	540 ⁽¹⁾	4,800 ⁽³⁾	4.0

(1) Adjusted for diversions from the basin.

(2) Occurred August 1955.

(3) Occurred March 1968.

TABLE 1-VII
MONTHLY RUNOFF (cfs)

Month	Concord River Below River Meadow Brook at Lowell, Mass.			Assabet River at Maynard, Mass.			Sudbury River at Framingham Center, Mass.		
	(DA = 405 Sq. Miles) Oct 1936-Sep 1970			(DA = 116 Sq. Miles) Jul 1941-Sep 1970			(DA = 75.2 Sq. Miles) Jan 1875-Sep 1970		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	580	1,135	160	193	439	38	42	264	-24
February	708	1,856	318	230	696	72	93	468	1.7
March	1,113	1,931	660	410	752	229	121	382	15.8
April	1,143	2,189	616	376	741	127	136	352	12.4
May	684	1,235	283	226	443	115	171	559	34.9
June	410	962	116	132	336	39	302	753	69
July	233	1,512	50	62	254	12	236	489	68.6
August	184	1,208	33.1	57	561	10	126	344	29.7
September	212	1,151	22.8	60	542	5	59	231	-24.9
October	238	1,079	38.3	70	375	10	23	401	-36.7
November	404	1,346	86.9	139	542	22	23	532	-39.0
December	571	1,152	133	165	458	36	30	345	-42.1
ANNUAL	540	889	242	177	286	74	113	188	42.0
(Inches)	17.9	30.1	8.11	20.5	33.5	8.7	20.4	33.9	7.6

and March 1968. Heavy rains during summer months caused the floods of July 1938, September 1954 and the record flood of August 1955.

b. Floods of record. Records of river stages at Framingham Center and pool elevations of Framingham Reservoir No. 1 have been maintained by the Metropolitan District Commission since 1875. In addition to the floods of this century, noteworthy floods were recorded in February 1886 and March of 1888; however, information about them is meager. At the Concord Street bridge, located within the area of proposed protection just upstream of Cochituate Brook, estimates have been made of past floods. These estimates are shown in table 1-VIII, "Pertinent Discharge-Frequency Data."

6. FLOOD FREQUENCY ANALYSIS

Discharge frequencies for the ungaged Sudbury River at Saxonville were derived through comparison of computed peak flood flows at Saxonville and statistical analysis of records from hydrologically similar streams in the same geographical area. The adopted discharge-frequency curve for the Sudbury River at Saxonville along with curves for the Assabet River, another tributary to the Concord River adjacent to the Sudbury, and Kettle Brook, a tributary to the Blackstone River, are shown on plate 1-2.

Frequencies for the gaged streams were determined using a Log Pearson Type III distribution as described in: "Statistical Methods in Hydrology," by L. R. Beard, CW-151, Sacramento District Corps of Engineers, January 1962. Curves are defined by the mean, standard deviation and skew of the logarithms of annual peak flows. Frequencies were also adjusted for length of record in accordance with Exhibit 40, and partial duration as described in paragraph 4-04 of the above referenced CW-151 report. The computed means and standard deviations for the Assabet River and Kettle Brook records plus the adopted values for the Sudbury River are listed in table 1-VIII. A regional skew coefficient of 0.5 was used based on a recently completed regional computer study of all stream gage records in southeastern New England.

The discharge-frequency data and stage-discharge curves for the Sudbury River were used to develop the stage-frequency data used in the economic analysis for the Saxonville project.

7. ANALYSIS OF FLOOD OF AUGUST 1955

As previously stated, the flood of August 17-19, 1955, resulting from hurricane "Diane," is the largest flood of record on the Sudbury River.

TABLE 1-VIII
PERTINENT DISCHARGE-FREQUENCY DATA

	<u>Assabet River at Maynard, Mass.</u>	<u>Kettle Brook at Worcester, Mass.</u>	<u>Sudbury River at Saxonville, Mass.</u>
Drainage Area (sq. mi.)	116	31.3	86
Period of Record (years)	29	48	-
August 1955 Flood (cfs)	4,250	3,970	4,400*
March 1936 Flood (cfs)	-	2,520	2,050*
Sept. 1954 " "	2,040	1,530	2,850*
March 1968 " "	3,620	1,100	2,100*
Mean Log	3.0456	2.650	2.820**
Standard Deviation	0.232	0.325	0.310**
Skew	0.50	0.50	0.50**

* Computed Flow
** Adopted Value

Climatological data associated with this storm indicate that two significant periods of rainfall were experienced, one on the 18th and one on the 19th, with an intervening period of eight hours of relatively insignificant precipitation. Rainfall varied from about 10 inches in the lower portions of the watershed near the local protection area to over 13 inches in remote portions of the headwaters. The storm, averaging about 12 inches over the entire basin, resulted in a peak flow at Saxonville of 4,400 cfs. The storm hyetograph on plate 1-3 is illustrative of the pattern and magnitude of the experienced rainfall over the basin.

Pertinent data on the system of reservoirs upstream of Saxonville were provided by the Department of Natural Resources and the Metropolitan District Commission of the Commonwealth of Massachusetts. Pool elevations, and spillway and outlet conditions during the 1955 flood were compiled and reported by Anderson-Nichols & Co., Inc., under contract to the Soil Conservation Service of the U.S. Department of Agriculture. Storage-discharge relationships were developed for each reservoir, and reservoir and channel routings were performed to reproduce observed pool elevations and downstream discharges to Saxonville.

The hydrographs of reservoir inflows, outflows, and pool elevations on plates 1-3 and 1-4 summarize the floodflows and timing of the August 1955 flood. It is important to note the relative contributing flows from each of the sub-watersheds.

a. For example, a peak outflow of 2,250 cfs has been calculated at Sudbury Reservoir. The relative size and configuration of this reservoir as compared to that of its drainage area are considerable, i.e., little rainfall is lost to infiltration and the outflow hydrograph has a quick response to rainfall. Had the Sudbury Reservoir been initially full, the peak outflow would have been an estimated 3,100 cfs.

b. The pool elevation of Ashland reservoir was dropped before the storm to facilitate workers in the area. This rather fortunate circumstance enabled the reservoir to store an estimated 2.5 to 3.0 inches of runoff, and consequently reduced its contribution to the flood at Saxonville somewhat.

c. It should also be observed that Framingham Reservoirs Nos. 1, 2 and 3 have little modifying effect on floods. However, the

rather long, flat and swampy reach of river above Reservoir No. 2 contains considerable natural valley storage and is instrumental in modifying and de-synchronizing peak flows.

d. Although Saxonville Pond itself has almost no storage for flood control, the river valley upstream as far as Reservoir No. 1 contains considerable natural flood plain storage and, as shown on plate 1-4, reduced flood peaks from Reservoir No. 1 to Saxonville by over 10 percent.

e. Only Framingham Reservoir No. 1 was full to spillway crest before the storm. Had all reservoirs been initially filled in 1955, the resulting peak discharges at Saxonville would have been approximately 40 percent greater than experienced. Though the probability of a major storm occurring with all reservoirs initially filled, may be remote, the possibility does exist.

8. UNIT HYDROGRAPH DEVELOPMENT

Six-hour unit hydrographs were developed for each of the component reservoir watersheds using the computer program 23-J2-L211, "Unit Hydrograph and Loss Rate Optimization," prepared by the Hydrologic Engineering Center, Corps of Engineers, Davis, California. Hydrograph data consisted of the computed August 1955 inflow hydrographs for Lake Cochituate, the local inflow to Framingham Reservoir No. 2, Sudbury Reservoir and Ashland Reservoir. Rainfall data were obtained from records published by the National Weather Service. Unit hydrographs for the other reservoirs and intervening drainage areas were developed by applying drainage area relationships to the derived unit hydrographs with due consideration given to topography and other runoff characteristics of each sub-watershed. The four unit hydrographs derived using the referenced computer program are shown on plate 1-5.

9. STANDARD PROJECT FLOOD DEVELOPMENT

a. General. The Standard Project Flood (SPF) is defined as that flood that may be expected to result from the most severe combination of meteorological and hydrological conditions that are considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations. The SPF, although a very infrequent event, is intended

as a practicable expression of the degree of protection that should be sought, if economically feasible, in the design of local protection works for Saxonville. The SPF was developed for the reaches of river at Saxonville above and below its confluence with Cochituate Brook.

b. Standard Project Storm. The Standard Project Storm (SPS) was determined based on criteria described in Civil Works Engineer Bulletin No. 52-8. The SPS rainfall, assumed to be uniformly distributed over the entire drainage area above Saxonville, was 13.5 inches in 96 hours, with a maximum of 11 inches falling during one 24-hour period.

Losses from infiltration, surface detention, transpiration, and intangible factors were assumed at the rate of 0.1 inches per hour, which was substantiated by analysis of previous storms in the Sudbury River watershed. Rates of precipitation, infiltration and rainfall excess for the 24-hour period of maximum precipitation are listed in table 1-IX in the chronological sequence used to compute the Standard Project Flood.

TABLE 1-IX
STANDARD PROJECT STORM RAINFALL

<u>Time in Hours</u>	<u>Rainfall in Inches</u>	<u>Infiltration in Inches</u>	<u>Rainfall Excess in Inches</u>
0	0	0	0
6	0.3	0.3	0
12	1.3	0.6	0.7
18	8.6	0.6	8.0
24	0.8	0.6	0.2

c. Inflow hydrograph development. Standard Project Flood inflow hydrographs for all the reservoirs and intervening local drainage areas were derived by applying the 6-hour rainfall excess values to the adopted 6-hour unit hydrographs. Inflow hydrographs for the Standard Project Flood are shown on plates 1-6 and 1-7.

d. Standard Project Flood routing. SPF inflows were routed through reservoir surcharge storage using the traditional relationship, "Inflow-Outflow = Change in Storage." Taking into account that the SPF could be preceded by a lesser storm, the assumptions were made that all reservoirs would be full to spillway crest and that all outlet gates would remain closed during the flood. The reservoirs are presently filled to capacity during certain seasons of the year. Since the Standard Project Flood by definition is a flood resulting from the most critical conditions in the basin, the revised SPF was developed assuming all reservoirs filled to capacity.

In turn, reservoir outflows were routed by the progressive average-lag method to the next downstream reservoir and combined with the local inflow for that downstream reservoir. For example, inflows of Ashland, Hopkinton and Whitehall reservoirs were individually routed through their respective pools. The resulting outflows were then routed downstream to Reservoir No. 2 and combined with the local inflow. The total inflow was then routed through the surcharge storage in Reservoir No. 2, and in turn became a major contributor to the inflow of Reservoir No. 1.

Similarly, flows from the tandem system of Sudbury Reservoir and Reservoir No. 3 were routed to Reservoir No. 1. Outflows from Reservoir No. 1 were then routed through the storage reach above Saxonville Pond, where the SPF was determined to be 10,000 cfs. This flow was adopted as the design flood for the reach of the Sudbury River from Saxonville dam downstream to the confluence with Cochituate Brook. Below Cochituate Brook, the SPF is approximately 11,900 cfs, as the peak outflows from Lake Cochituate can be expected to nearly coincide with those peak discharges over Saxonville Dam.

The hydrographs presented on plates 1-6 and 1-7 summarize the SPF inflows, outflows and pool elevations for the entire reservoir system.

10. INTERIOR DRAINAGE HYDROLOGY

a. General. The interior drainage analysis presented in the 1965 Survey Report was developed in accordance with design procedures outlined in EM 1110-2-1410, "Interior Drainage of Leveed Urban Areas: Hydrology."

b. Description of area. The interior drainage area within the system of dikes and floodwalls is approximately 35 acres of which about 75 percent is industrial, residential, or commercial. Paved parking areas and small grassed lots comprise the remaining 25 percent. The slope of the topography is relatively flat. The Class I (concentrated commercial and industrial sections) has been selected as being indicative of the area.

The storm drainage system, which is separate from the sanitary sewer system, includes several outfalls to the river. The 35-acre drainage area includes about seven acres which are normally intercepted by storm drainage and discharged outside of the area. During intense rainfall, it is assumed that most of the runoff would bypass the catch basins and flow into the protected area.

c. Unit hydrographs. Synthetic one-hour unit hydrographs were developed for the 2-, 10- and 100-year rainfall frequencies. These adopted one-hour unit hydrographs are shown on plate 1-8. Peak values of the one-hour unit hydrographs for the 35 acres are tabulated below.

<u>Frequency</u> (years)	<u>Peak</u> (cfs)	<u>t_p</u> (hrs.)
2	26	1.00
10	27	0.96
100	34	0.77

d. Design storm. Precipitation data for the 2-, 10- and 100-year frequency storms were taken from the U.S. Weather Bureau Technical Paper No. 40, "Rainfall Frequency Atlas of the United States," dated May 1961. Infiltration and other losses were assumed at a rate of 0.10 inch per hour. A plot of hourly rainfall amounts for the 2-, 10- and 100-year frequency storms is shown on plate 1-8.

e. Runoff hydrographs. Runoff hydrographs resulting from the 2-, 10- and 100-year frequency storms were computed by applying rainfall excesses derived for each rainfall frequency to the synthetic unit hydrographs. The inflow hydrographs to the protected area, not including seepage, have peaks of 30, 49 and 88 cfs, respectively. The runoff hydrographs are shown on plate 1-8.

f. Seepage. In preauthorization studies, it was considered that the maximum rate of seepage would be 8.5 cfs and the process

water from the Roxbury Carpet Company would be about 1.5 cfs. Presently, treatment facilities are being built which will pump the process water, however, seepage will be increased due to the increase in design flow. The 1.5 cfs capacity, originally for process water, was therefore retained to allow for added seepage resulting in a total seepage capacity of 10 cfs. Subdrains will be provided along the landside toe of dike to carry the seepage flow to the pumping station.

g. Ponding. There are no existing ponding areas capable of storing the interior runoff during the design storm, nor are there any existing provisions for diversion. The only undeveloped land of any appreciable size is located adjacent to the pumping station. This area, amounting to approximately 5.5 acres, includes a 2.5 acre paved parking lot. The lowest ground elevation behind the proposed dike and wall will be 118 feet msl. The storage capacity of the ponding area at elevation 121 feet msl will be 1.3 acre-feet, equivalent to about 0.44 inch of runoff from the 35 acres. The area-capacity curve is shown on plate 1-8.

h. Pumping station. One pumping station to handle interior runoff is required at the project. The runoff hydrographs of the 2-, 10- and 100-year storms, including seepage and process water, were routed through the ponding area, assuming various pumping capacities. A graphical presentation of ponding elevations resulting from the 2-, 10- and 100-year rainfall frequency storms with various pumping capacities is shown on plate 1-8. A pumping station capacity of 35 cfs was selected, resulting in shallow inundation to elevations of 118.8 feet msl for stage A, 121 feet msl for stage B and 123 feet msl for stage C. The storage area up to elevation 121 feet msl lies principally in the permanent easement area for the pumping station.

The probability of experiencing a 2-, 10- or 100-year frequency rainfall coincident with high river stages is indeterminate but considered quite remote. Peak stages in the river occur about 30 hours after intense rainfall, therefore, any intense runoff during high river stage would most probably be the result of a secondary storm rather than the primary flood producing event.

The design 35 cfs pumping capacity is equivalent to a runoff rate of 1 inch per hour and will provide a high degree of protection against interior flooding during high river stage. Peak hourly

rainfall during the record August 1955 flood was approximately 1.7 inches per hour. In the event that pumping capacity is exceeded, ponding will be shallow due to the flatness of the area and of short duration resulting in minimal damage.

i. Gravity outfall. Gravity outfalls through the line of protection will be designed to pass a 100-year frequency discharge (88 cfs) with a normal river stage. A sluice gate and a flap valve will be provided on the outfall.

j. Interceptor drain. All interior drainage trapped by the proposed protection will be collected with an interceptor drain and carried to the pumping station as shown on plate 1-9. Existing drainage systems will be connected to the new interceptor and most structures on the line will be furnished with grates to pick up surface flows. The alignment of the new interceptor generally follows the landside toe of the dike.

The interceptor drains and inlets have been designed for a 10-year storm runoff, discharging to normal river stage, using the rational formula and a time of concentration of 20 minutes. This 10-year peak discharge is about 40 percent greater than the peak discharge coincident with a high river stage when the interceptor would be surcharged and some modifying ponding at catch basins would be expected and acceptable. The design discharges in both cases allow for extensive improvements in collector systems in the future by local interests.

PART II - HYDRAULIC ANALYSIS

11. GENERAL

This part of the memorandum presents the hydraulics used as a basis for the design of flood control works along the Sudbury River in Saxonville. The proposed plan of improvement includes a series of walls, gates and dikes along the left bank of the river between Saxonville Dam and Danforth Street bridge, a distance of 3,800 feet. The reach of river, as shown in the plan and profile on plate 1-9, is roughly U-shaped and extremely flat after an initial drop of about 6 feet in the first 1,000 feet below Saxonville Dam.

12. WATER SURFACE PROFILES

a. General. Water surface profiles were determined using the computer program 723-X6-L202A, "Water Surface Profiles," developed by the Hydrologic Engineering Center, Davis, California. The method used to compute profiles is similar to Method 1, Backwater Curves in River Channels, Engineering Manual 1110-2-1409, U.S. Army Corps of Engineers, 7 December 1959. Computed water surface profiles for the improved channel of the Standard Project Flood and of discharges equal to the August 1955 flood are shown on plate 1-9.

b. Manning's "n". Initial estimates of Manning's roughness coefficient were made based on channel slope, expected depth of flow, structural development and the type and condition of vegetal cover in the channel and overbank areas. Values of "n" were then adjusted by trial and error in an effort to reconstitute the observed water surface profile of the August 1955 flood. Adopted "n" values for the left overbank, right overbank and channel areas are .07, .07 and .035, respectively.

c. Transition losses. Energy losses due to contractions and expansions in cross sectional area of flow were computed using coefficients of 0.3 and 0.5 for contraction and expansion, respectively. Head losses, h_l , between cross sections were thus computed as $h_l = .3\Delta h_v$ for contractions and as $h_l = .5\Delta h_v$ for expansions, where Δh_v equals the absolute difference in velocity heads between cross sections.

d. Cross-section data. Twenty-four cross sections, including bridge cross sections, were required along the river to describe the existing channel and valley. Data were obtained from field surveys by the Corps of Engineers, U.S. Geological Survey quadrangle sheets, and from bridge plans. On the basis of field observations, data were corrected for recent encroachments on the flood plain in the vicinity of the Concord Street bridge.

In computing water surface profiles for improved conditions, changes in cross sections were made as reflected on plate 1-9. Channel relocation and improvement will extend from the Danforth Street bridge, a distance of approximately 1,200 feet upstream to the New York Central Railroad bridge. The straightened channel will be trapezoidal with a bottom width of 60 feet and side slopes of 1 on 2-1/2. Computations were made for a channel with a slope

of .00083. For purposes of the hydraulic analysis, the height of protection works on the left bank was assumed at an elevation that the SPF discharge could not overtop. The right bank side slope was tied into natural ground.

Upstream of the realigned trapezoidal channel, cross sectional modifications were made on the left bank as follows: levees were programmed at the railroad bridge and at Concord Street bridge to reflect vertical flood control works; the dike upstream of Concord Street was programmed on the channel bank with 1 on 2-1/2 side slopes riverside; and the concrete floodwall extending from the southwest corner of the Roxbury Carpet Company upstream to Saxonville Dam was programmed as a vertical levee.

e. Discharge rating curves. Rating curves at selected control points along the river for both existing and improved conditions are presented on plates 1-10 and 1-11. The stage-discharge relationships for the sections below the Danforth Street bridge and above Concord Street bridge were determined for existing conditions based on historical data and the slope area method. It is noted that flood stages at Danforth Street are significantly affected by downstream backwater from the large "Sudbury Swamp" located downstream. These high tailwater conditions effect flood stages appreciably throughout most of the Saxonville reach, resulting in relatively low velocities and gradients. The possibility of significantly lowering downstream backwater by downstream channel improvement was investigated but considered impractical.

Water surface profiles for a wide range of discharges were created for the purpose of developing a rating curve upstream of Concord Street for improved conditions. The profiles were computed using starting water surface elevations for existing conditions downstream of the Danforth Street bridge. It was determined that the channel improvements would have an insignificant effect on stage-discharge relationships downstream of Danforth Street bridge.

Spillway discharge rating curves for existing and improved conditions for Saxonville Dam are shown on plate 1-11. These relationships were computed using the weir formula, $Q = CLH^{1.5}$, where:

- Q = discharge in cfs
- C = discharge coefficient (3.0 used for stone crest; 3.3 used for flashboards)
- L = length of overflow section
- H = head (pool stage minus elevation of overflow section in feet)

It should be noted that at elevation 148 feet msl the rating curve for improved conditions indicates a higher stage-discharge relationship than that for existing conditions. The plan of improvement includes heightening of the left portion of the dam. Consequently, flows greater than 2,200 cfs will be confined to the spillway section, rather than overflow the left wall as they have in the past.

13. EFFECT OF PROJECT ON FLOOD HEIGHTS

Several computer runs were made using the program "Water Surface Profiles" to determine the effect of the proposed project on flood heights. A wide array of discharges was used for both existing and improved conditions. It was found that excavation and channel straightening downstream of the Penn Central Railroad would slightly lower river stages upstream to Saxonville Dam. While some cross sectional area would be lost due to improvements, increased velocities would more than compensate for the loss of area. The diverging rating curves for upstream of Concord Street bridge show the magnitude of river stage reduction as related to discharge.

14. VELOCITIES

Maximum normal flow velocities vary from about 5 feet per second in the improved trapezoidal channel below the railroad bridge to approximately 9 feet per second in the relatively steep natural channel in the vicinity of the Roxbury Carpet Company for the Standard Project Flood. Flow velocities of a flood of the same magnitude as the August 1955 flood would be approximately 60 to 70 percent of the SPF velocities. Computed velocities for the SPF and 1955 flood are indicated on the profiles of the improved channel shown on plate 1-9.

15. FLOW CLASSIFICATION

Flow throughout the project reach is "tranquil" as defined in EM 1110-2-1601, "Hydraulic Design of Flood Control Channels." Under design flow conditions, Froude numbers vary from about 0.2 to 0.4.

16. HYDRAULICS OF BRIDGES

As shown on plate 1-9, the reach of the Sudbury River at Saxonville is crossed by four bridges. In determining head losses through bridges for the Standard Project Flood, the "normal bridge routine"

option of the computer program, "Water Surface Profiles," was used in all cases. The "normal bridge routine" is applicable to bridges under high submergence or in cases where low flow is experienced. The Danforth Street and Central Street bridges, at the extreme lower and upper ends of the project, respectively, have adequate openings to pass the SPF under low flow control. Consequently, head losses are negligible.

On the other hand, the Concord Street bridge and the railroad bridge would be completely submerged for any flow greater than 6,500 cfs. Total head losses through these bridges for the SPF amounted to approximately 0.9 foot. In past reports, recommendations have been made to abandon and remove the railroad bridge and to reconstruct Concord Street bridge. These recommendations indubitably have merit, but have been determined to be economically unjustifiable.

17. FREEBOARD DESIGN

The freeboard of a channel is the vertical distance measured from the design water surface to the top of a wall or levee. In accordance with considerations presented in EM 1110-2-1601 and Engineer Bulletin 54-14, a minimum freeboard of 3 feet for earth dikes and 2 feet for concrete walls was adopted for Saxonville.

Hydraulic ratings of the river channel indicate that an additional 2,000 cfs flow can be conveyed for each additional foot rise above design stage. The adopted freeboard therefore provides ample allowance for greater than design discharge plus ample protection against overtopping due to backwater effects from debris and other obstructions.

It is noted that at the downstream end of the project at Danforth Street the revised design height of dike is higher than the elevation of Danforth Street. It is planned to extend the dike across Danforth Street to high ground on the other side and to leave an opening at the street. Because this added height is within the freeboard range it is planned to provide freeboard protection by sandbagging this opening.

18. RIPRAP DESIGN

The riverward slopes of dikes and disturbed areas at the toe of floodwalls will be protected from erosion with a layer of stone riprap. The design of riprap protection was based on the "tractive

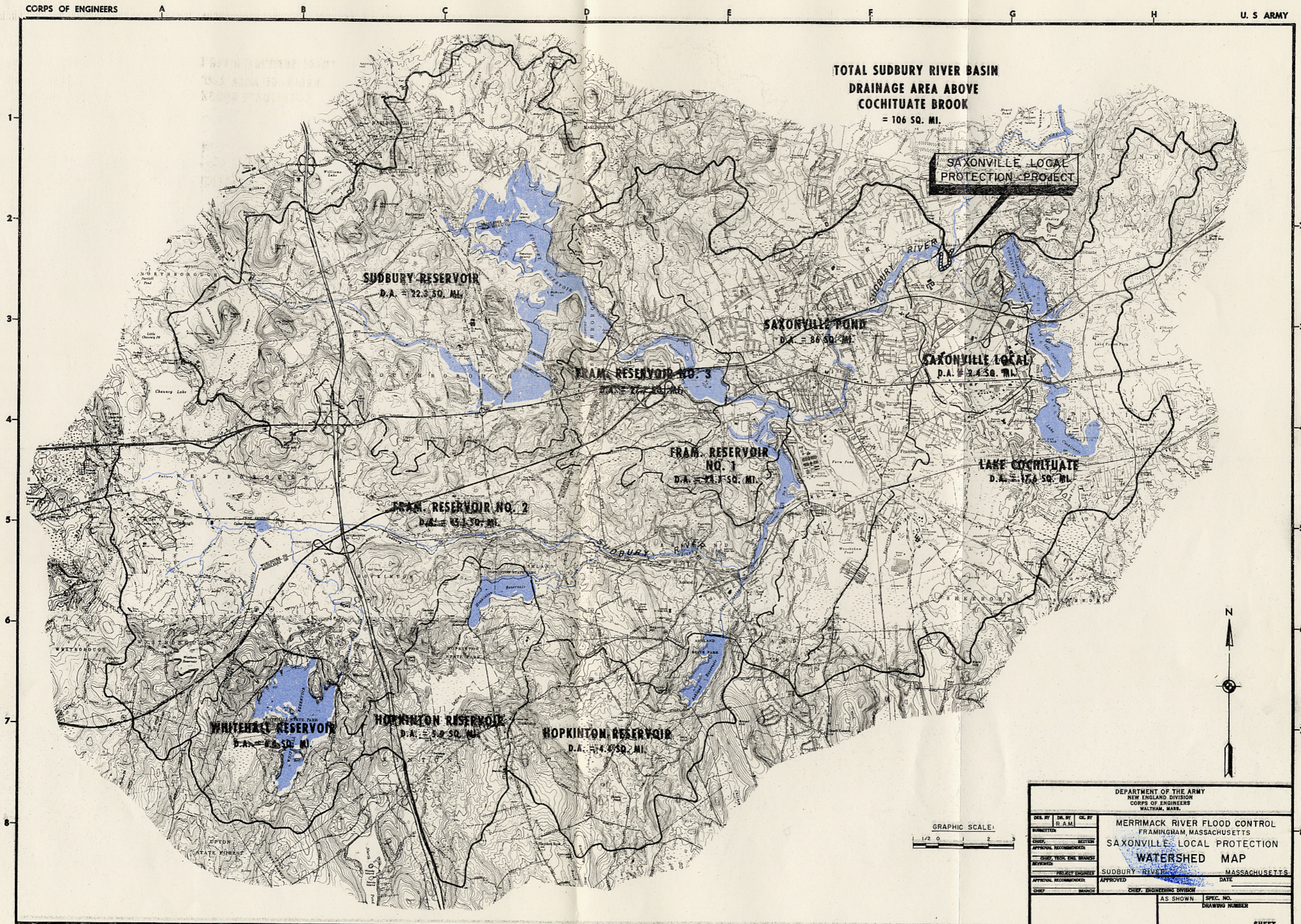
force theory" presented in Engineer Technical Letter No. 1110-2-60 entitled, "Criteria for Riprap Channel Protection," dated 13 June 1969.

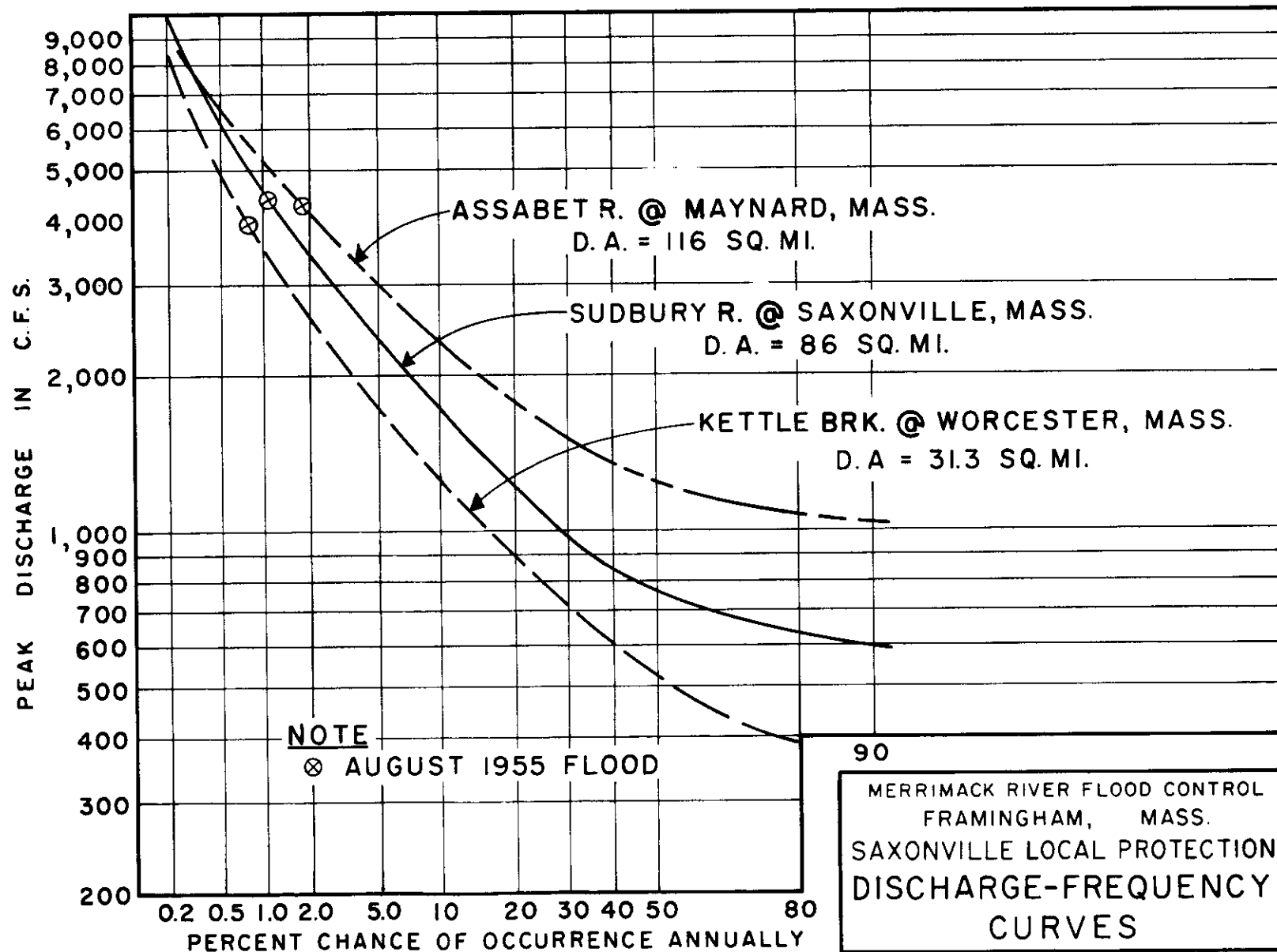
The stability of stone riprap against movement by tractive force is related to the equivalent diameter of the 50 percent by weight finer stones designated D50 minimum. Based on information in the above referenced report, a relationship was developed between depth of flow, friction slope and permissible D50 minimum.

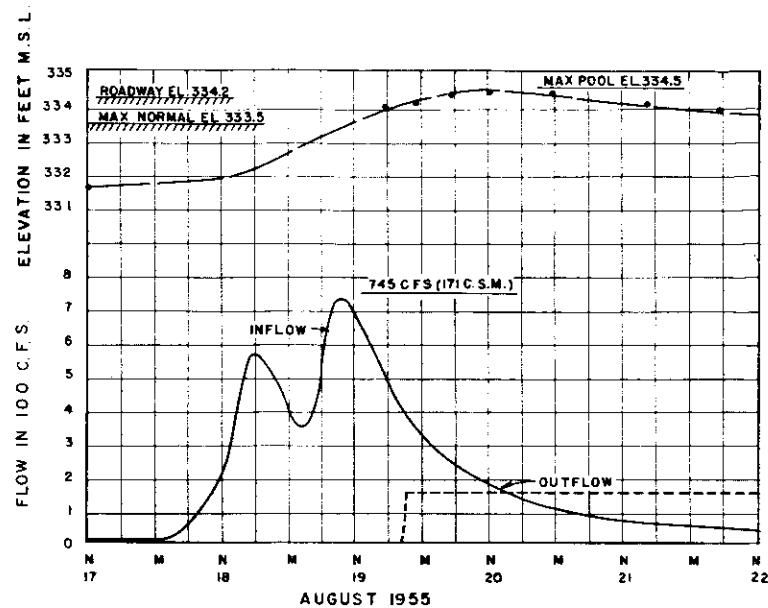
D50 minimums were computed for the side slopes and channel bottoms at several cross sections of the improved channel and for the side slopes of the proposed dike upstream of Concord Street. Depths of flow and friction slopes used in the analyses were the maximum derived from the backwater studies previously discussed. Pertinent data and the computed D50 minimums are summarized below in table 1-X. Computed D50 minimums being relatively low, a minimum riprap thickness of one foot will be adopted except at the upstream end (sec. 29+00) where 18 inches will be required. Riprap details will be presented in Design Memorandum No. 4, "Embankments & Foundations."

TABLE 1-X
HYDRAULIC DATA FOR CHANNEL RIPRAP DESIGN

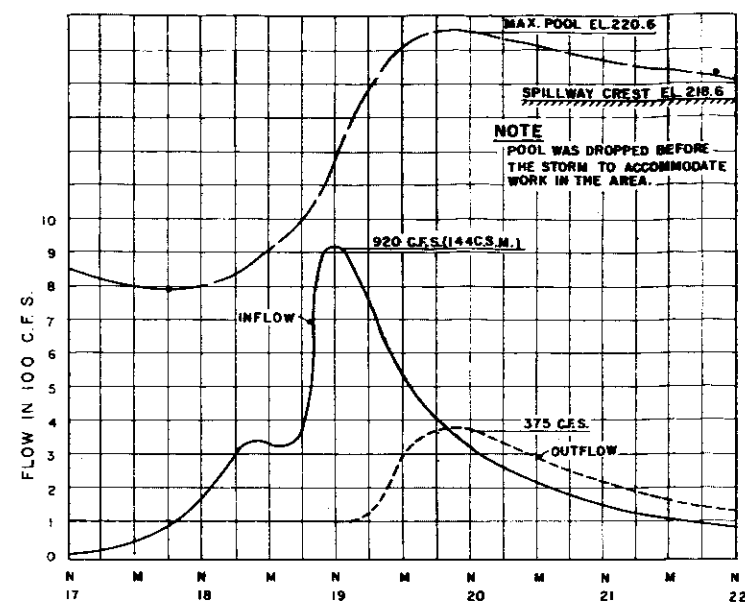
Cross Section Number	Cross Section Location	SPF Depth of Flow (A)	Velocity (ft/sec)	Friction Slope	D50 Minimums	
					Level Channel Bottom	Side Slope 1:2.5
2+00	100 ft. upstream of Danforth St.	18.6	5.6	0.0006	0.15	0.18
8+00	Just downstream of Cochituate Brk.	18.5	5.0	0.0004	0.12	0.14
12+90	50 ft. downstream of RR bridge	18.4	4.0	0.0012	0.30	0.35
15+70	50 ft. upstream of Concord St.	19.0	5.4	0.0004	NA	0.15
29+00	Just above river's confluence with small stream; about 1,400 ft. upstream of Concord St.	19.9	5.3	0.0018	NA	0.65



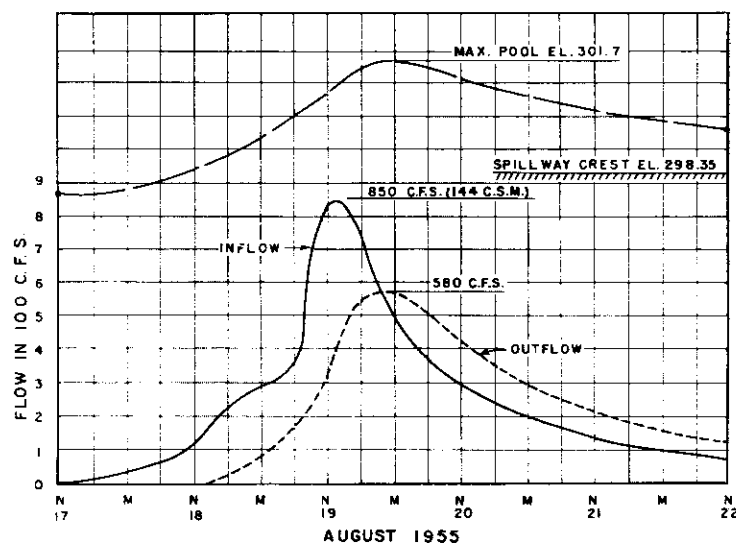


**WHITEHALL RESERVOIR**

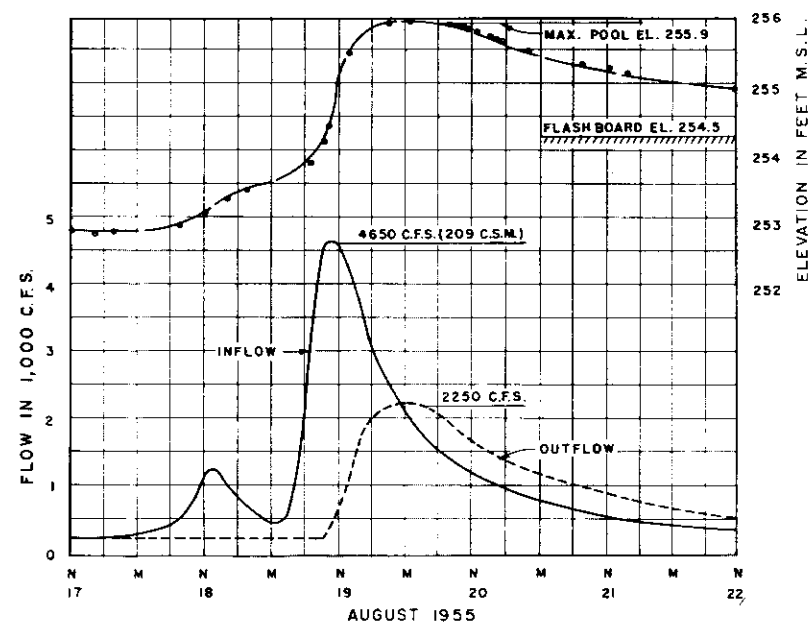
(D.A. = 4.35 SQ. MI.)

**ASHLAND RESERVOIR**

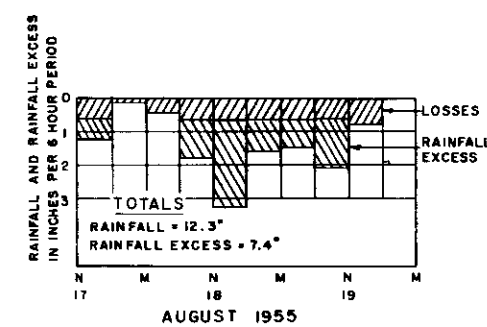
(D.A. = 6.4 SQ. MI.)

**HOPKINTON RESERVOIR**

(D.A. = 5.9 SQ. MI.)

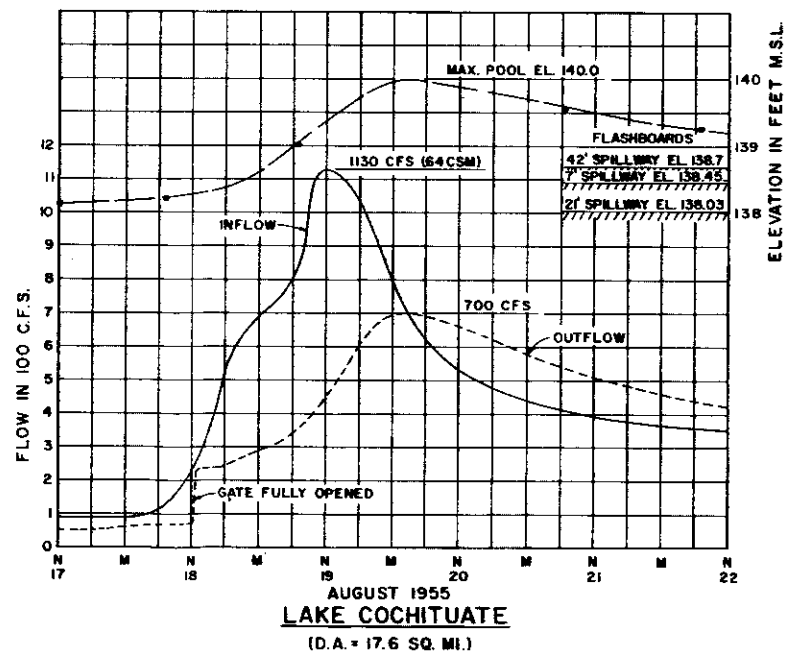
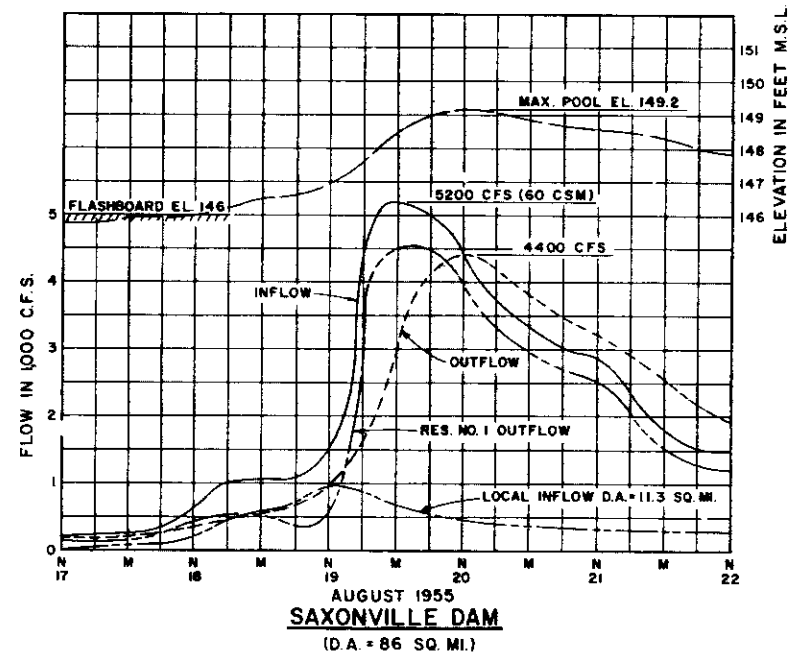
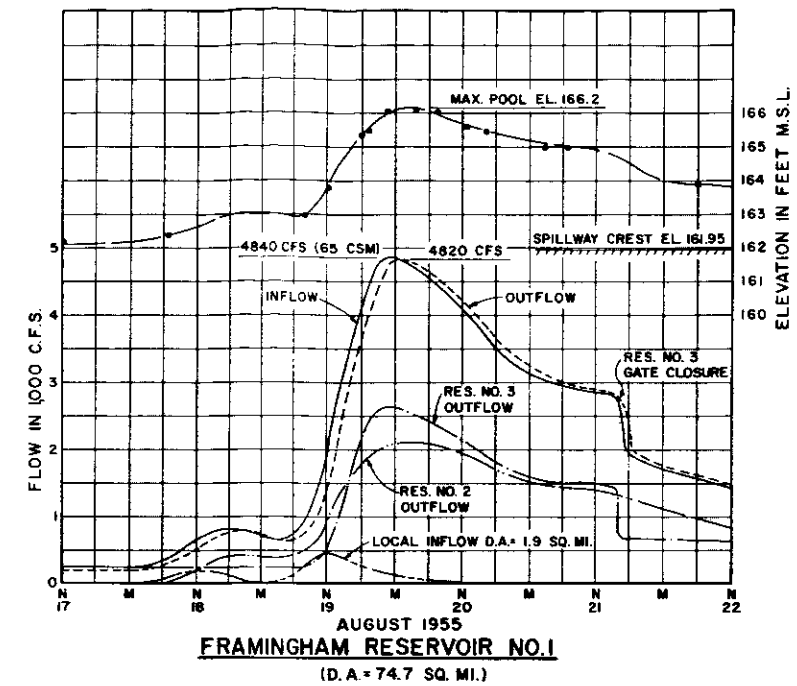
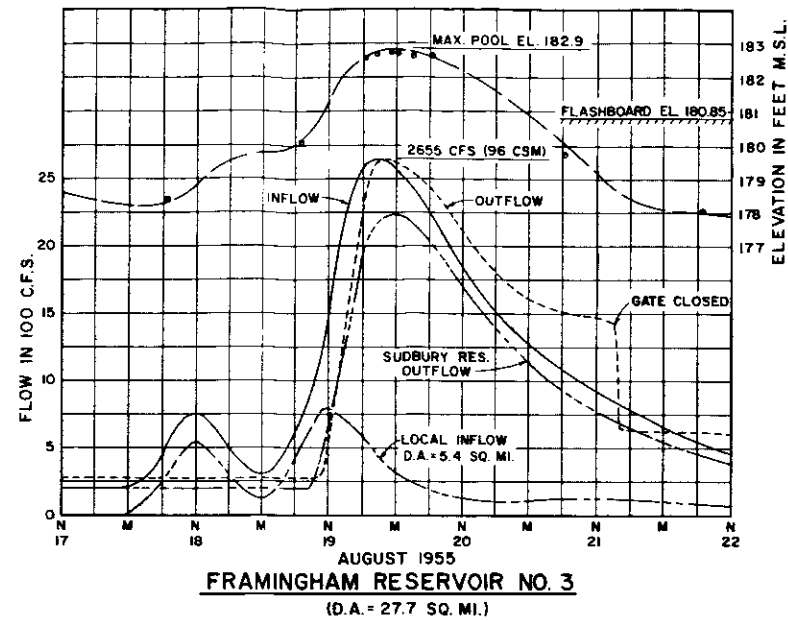
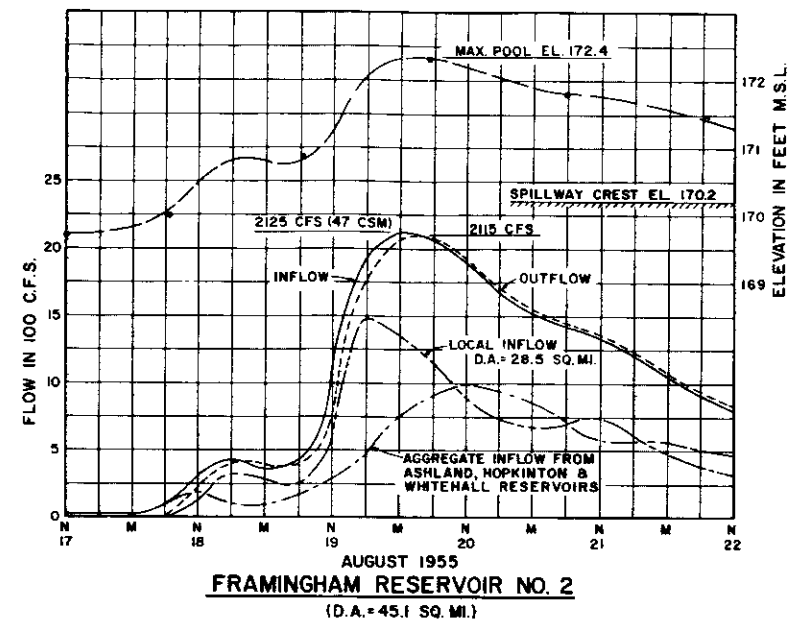
**SUDBURY RESERVOIR**

(D.A. = 22.3 SQ. MI.)

**HYETOGRAPH**

NOTE
ABOVE GRAPH DEPICTS AVERAGE MAGNITUDE
AND PATTERN OF RAINFALL AND RAINFALL
EXCESS FOR THE ENTIRE SYSTEM WATERSHED.

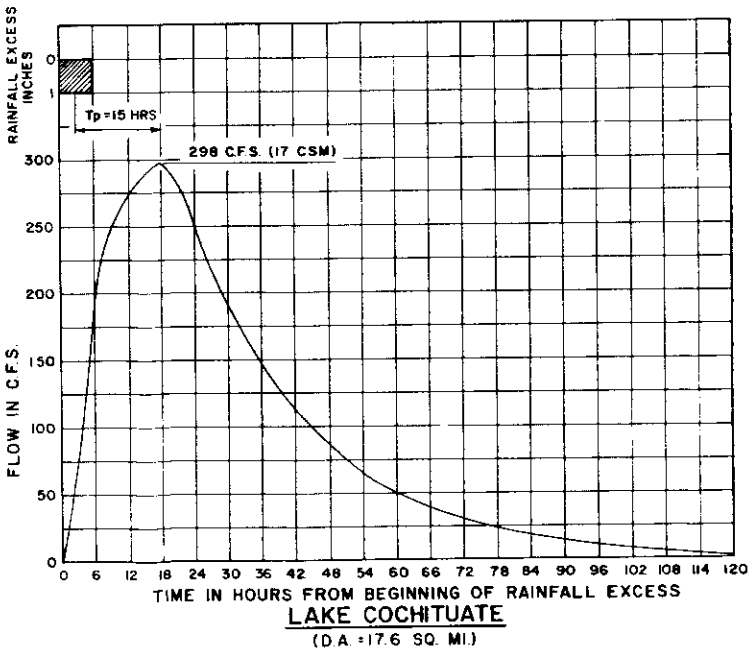
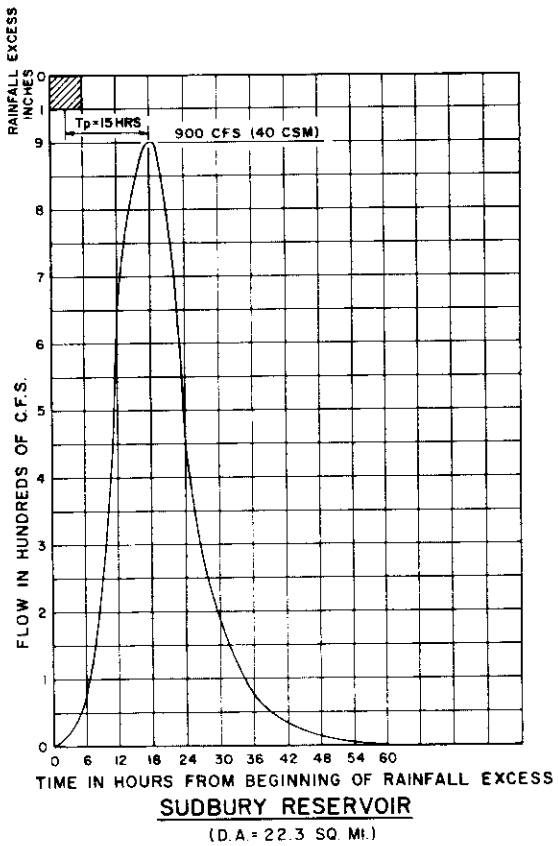
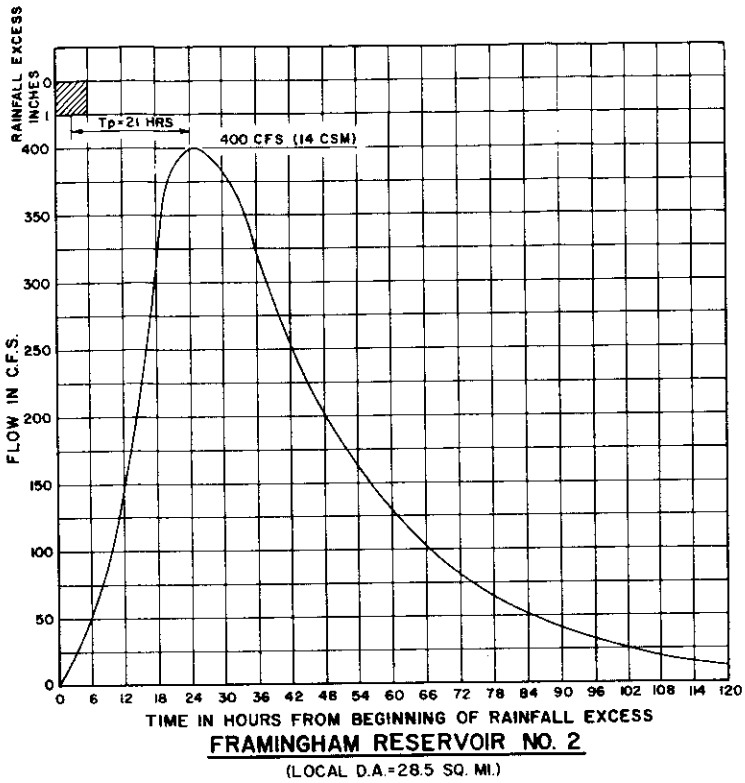
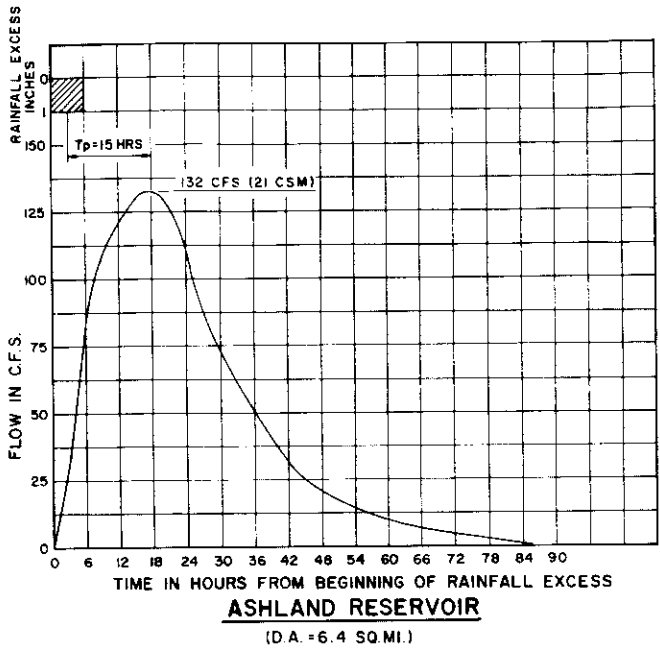
DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.			
MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS			
SAXONVILLE LOCAL PROTECTION FLOOD OF AUGUST 1955			
SUDBURY RIVER		MASSACHUSETTS	
APPROVED		DATE	
SCALE		SPEC. NO.	
DRAWING NUMBER		SHEET	



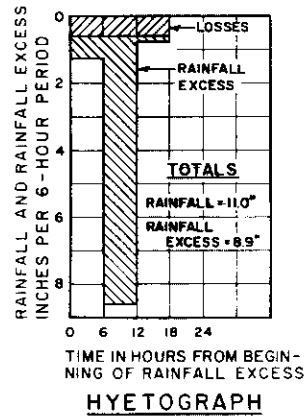
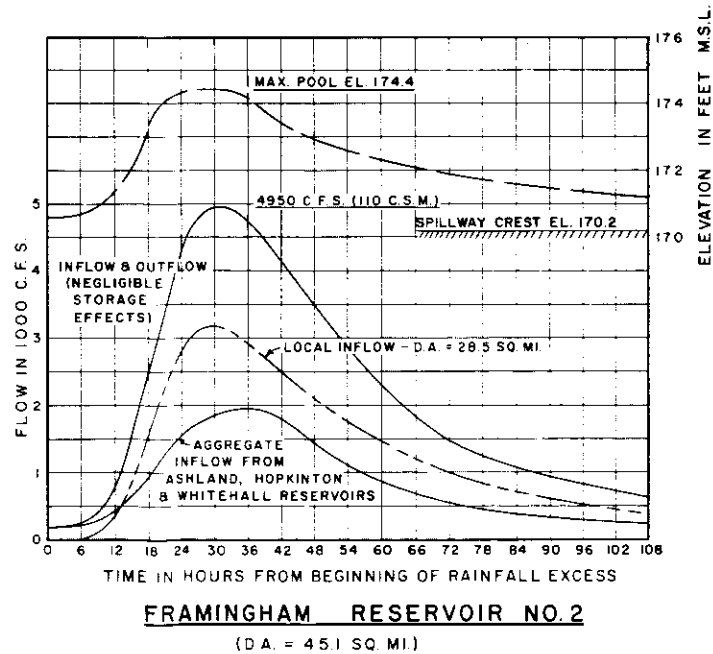
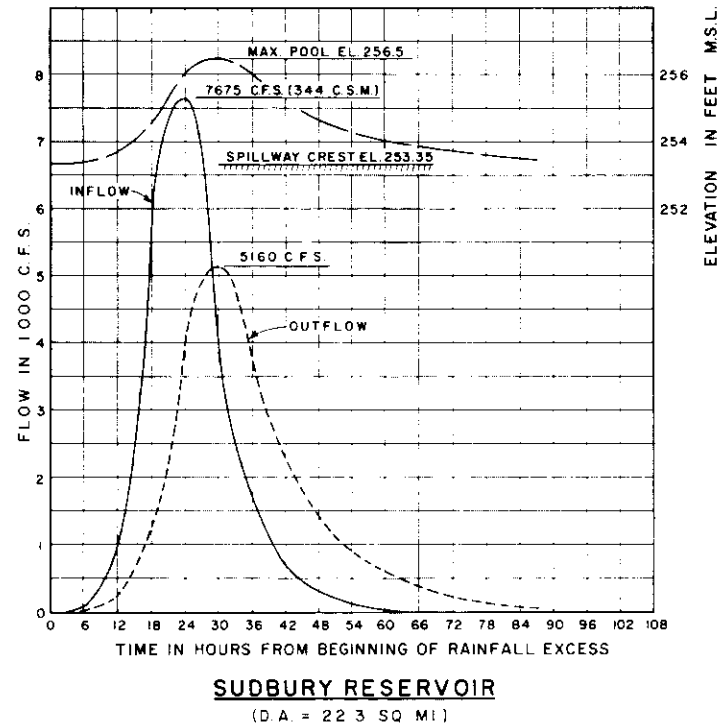
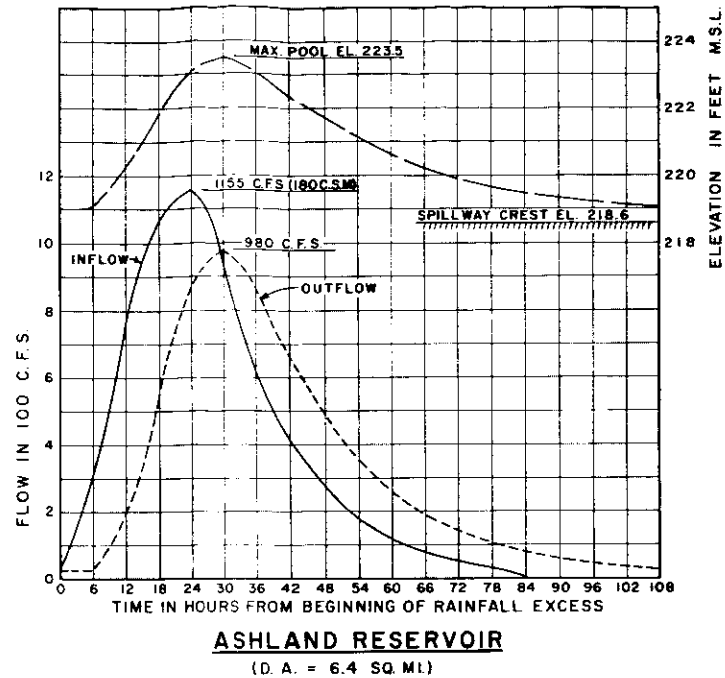
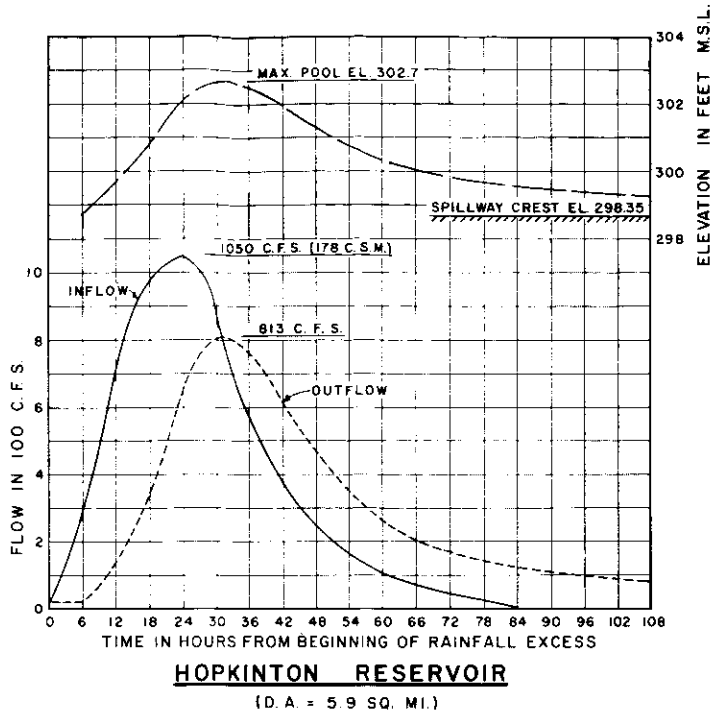
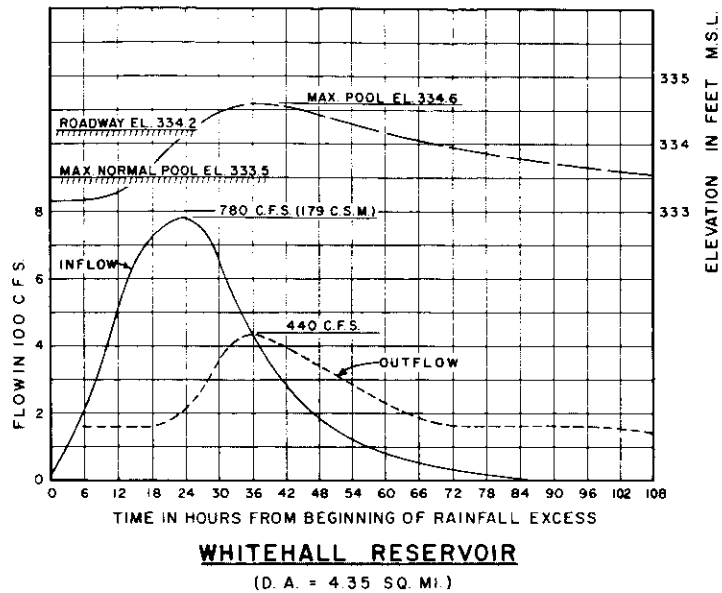
NOTE:

O OBSERVED POOL STAGES

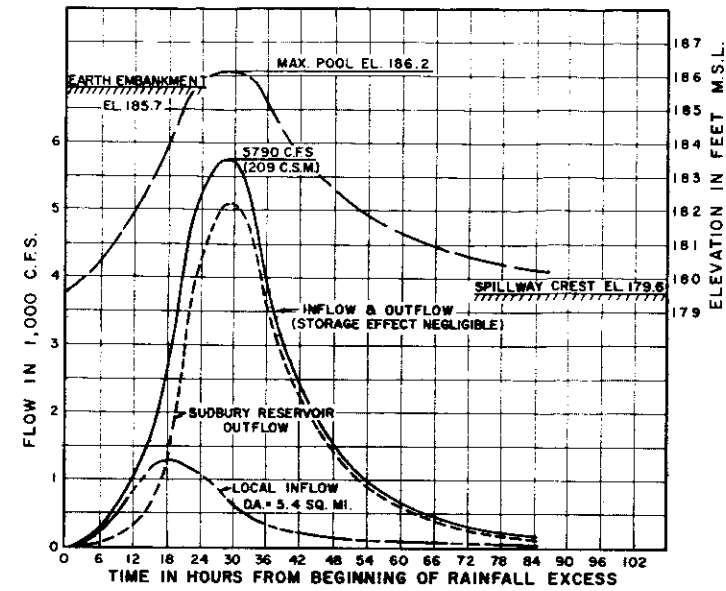
DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.		
MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS SAXONVILLE LOCAL PROTECTION FLOOD OF AUGUST 1955		
DESIGNED BY CHECKED BY APPROVED BY DATE	PROJECT NUMBER SAXONVILLE RIVER APPROVED BY DATE	MASSACHUSETTS DATE
SCALE: NONE		SHEET NO.



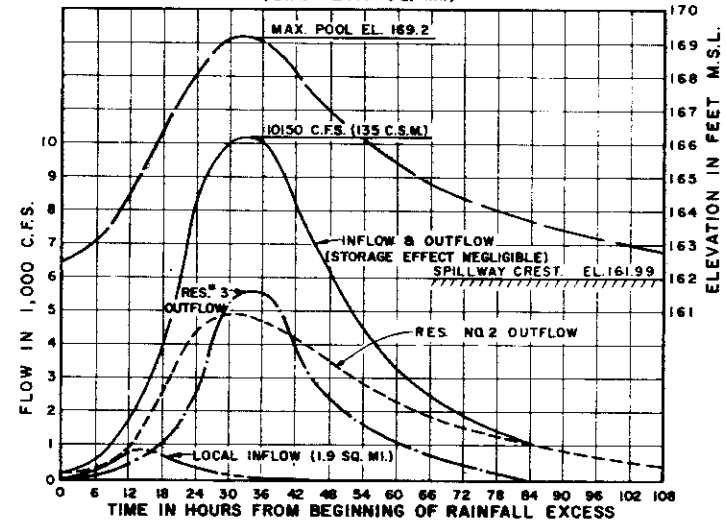
DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.			
MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS			
SAXONVILLE LOCAL PROTECTION			
6 - HOUR UNIT HYDROGRAPHS			
SUBBURY RIVER		MASSACHUSETTS	
APPROVED		DATE	
SPECIAL AGENT IN CHARGE		SPECIAL AGENT IN CHARGE	
SCALE		SPEC. NO.	
DRAWING NUMBER			
SHEET			



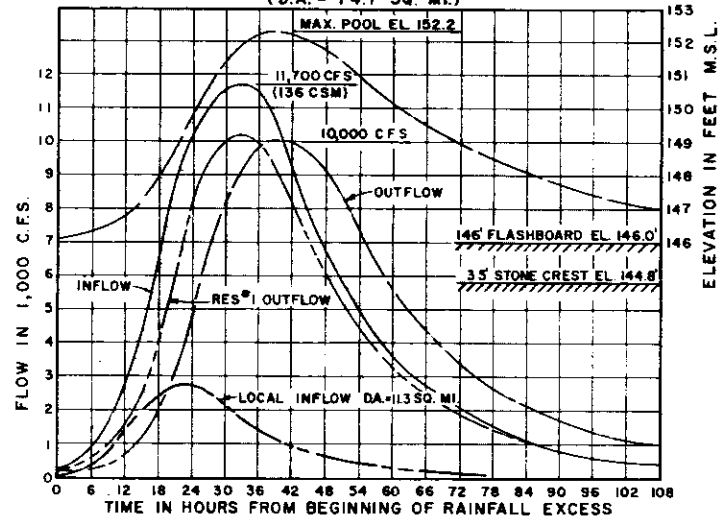
DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.			
MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS			
SAXONVILLE LOCAL PROTECTION STANDARD PROJECT FLOOD			
SUBBURY RIVER		MASSACHUSETTS	
APPROVED		DATE	
CHIEF, ENGINEERING DIVISION		SCALE	
SPEC. NO.		DRAWING NUMBER	
SHEET			



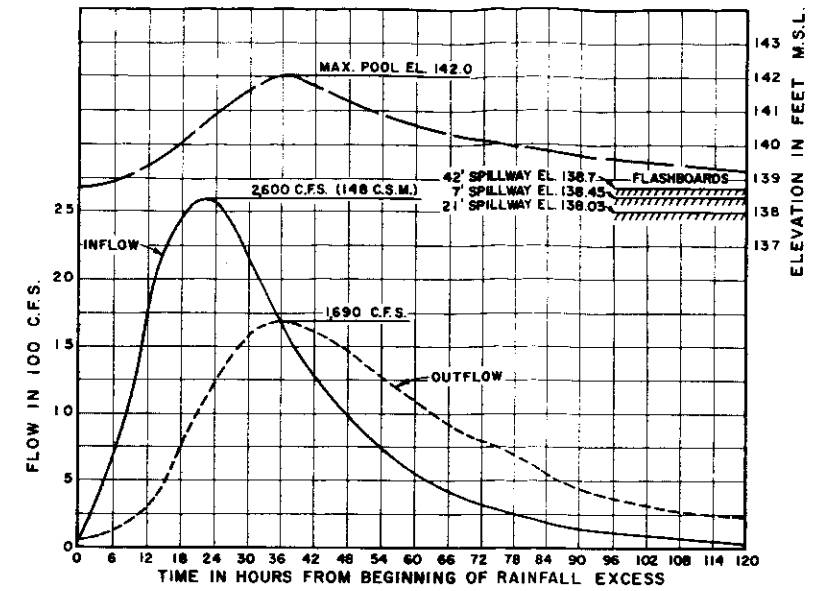
FRAMINGHAM RESERVOIR NO. 3
(D.A. = 27.7 SQ. MI.)



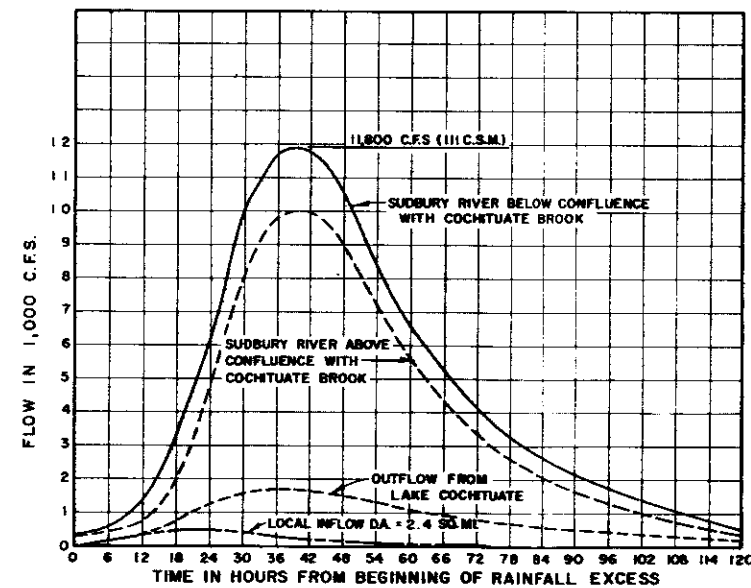
FRAMINGHAM RESERVOIR NO. 1
(D.A. = 74.7 SQ. MI.)



SAXONVILLE DAM
(D.A. = 86 SQ. MI.)

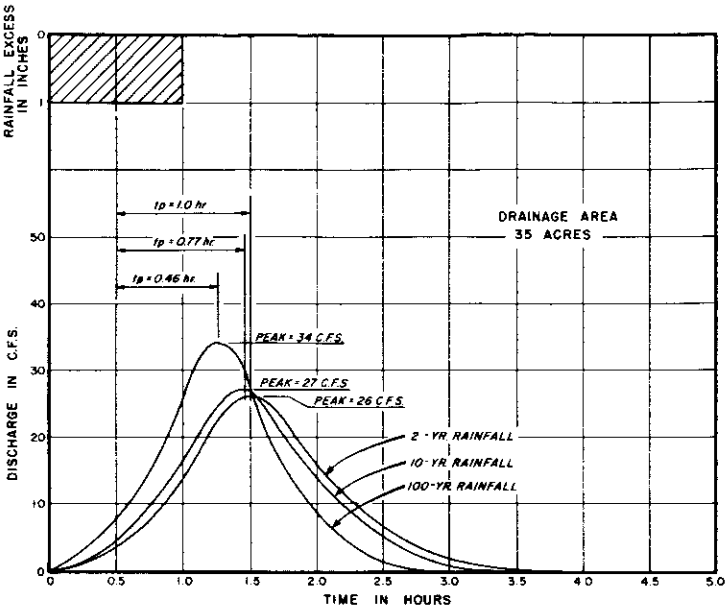


LAKE COCHITUATE
(D.A. = 17.6 SQ. MI.)

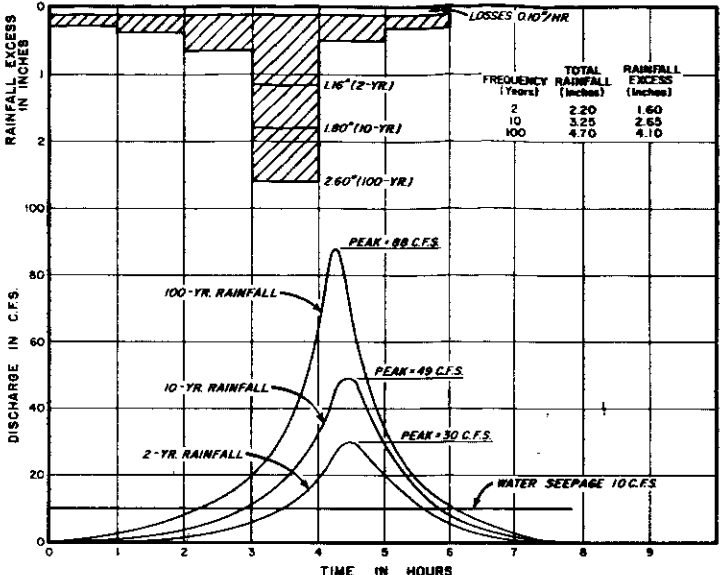


SUDBURY RIVER BELOW CONFLUENCE
WITH COCHITUATE BROOK
(D.A. = 106 SQ. MI.)

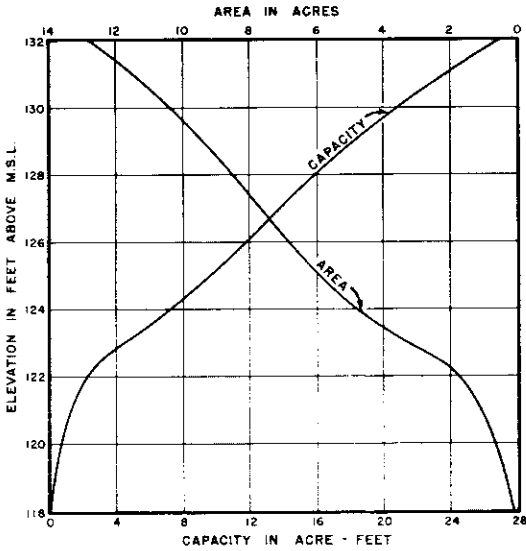
MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS	
SAXONVILLE LOCAL PROTECTION STANDARD PROJECT FLOOD	
SUDBURY RIVER MASSACHUSETTS	
APPROVED	DATE
SCALE	SPEC. NO.
DRAWING NUMBER	
SHEET	



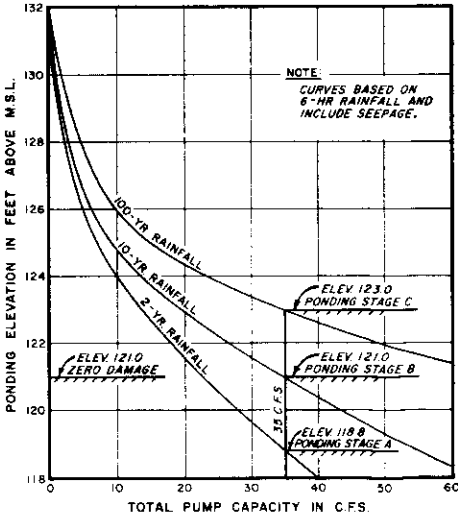
ADOPTED ONE HOUR UNIT HYDROGRAPHS



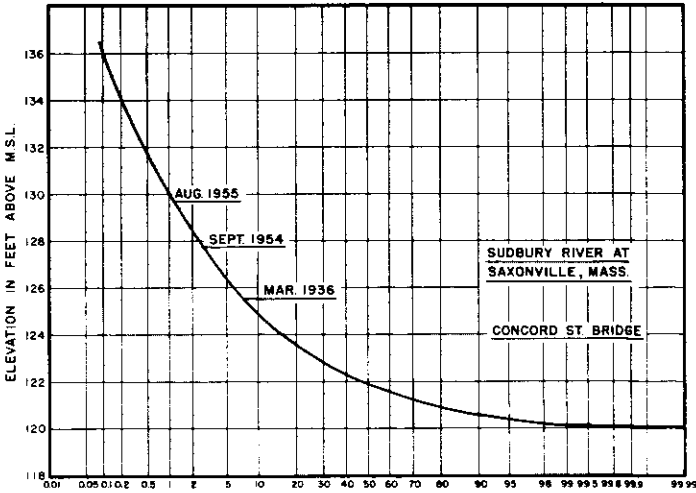
RUNOFF HYDROGRAPHS



AREA - CAPACITY CURVES

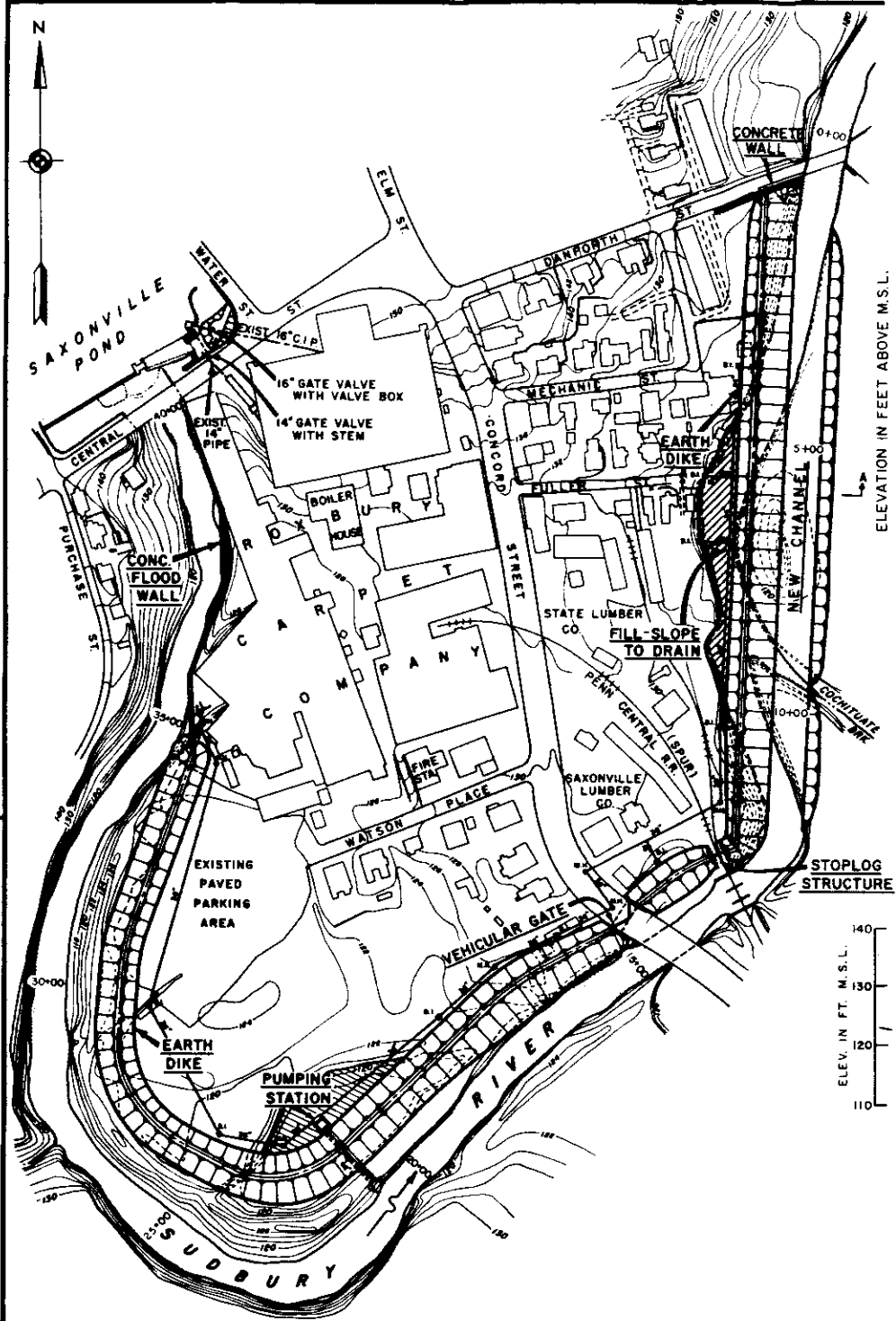


PONDING ELEVATION VS. PUMP CAPACITY



ELEVATION - FREQUENCY CURVE

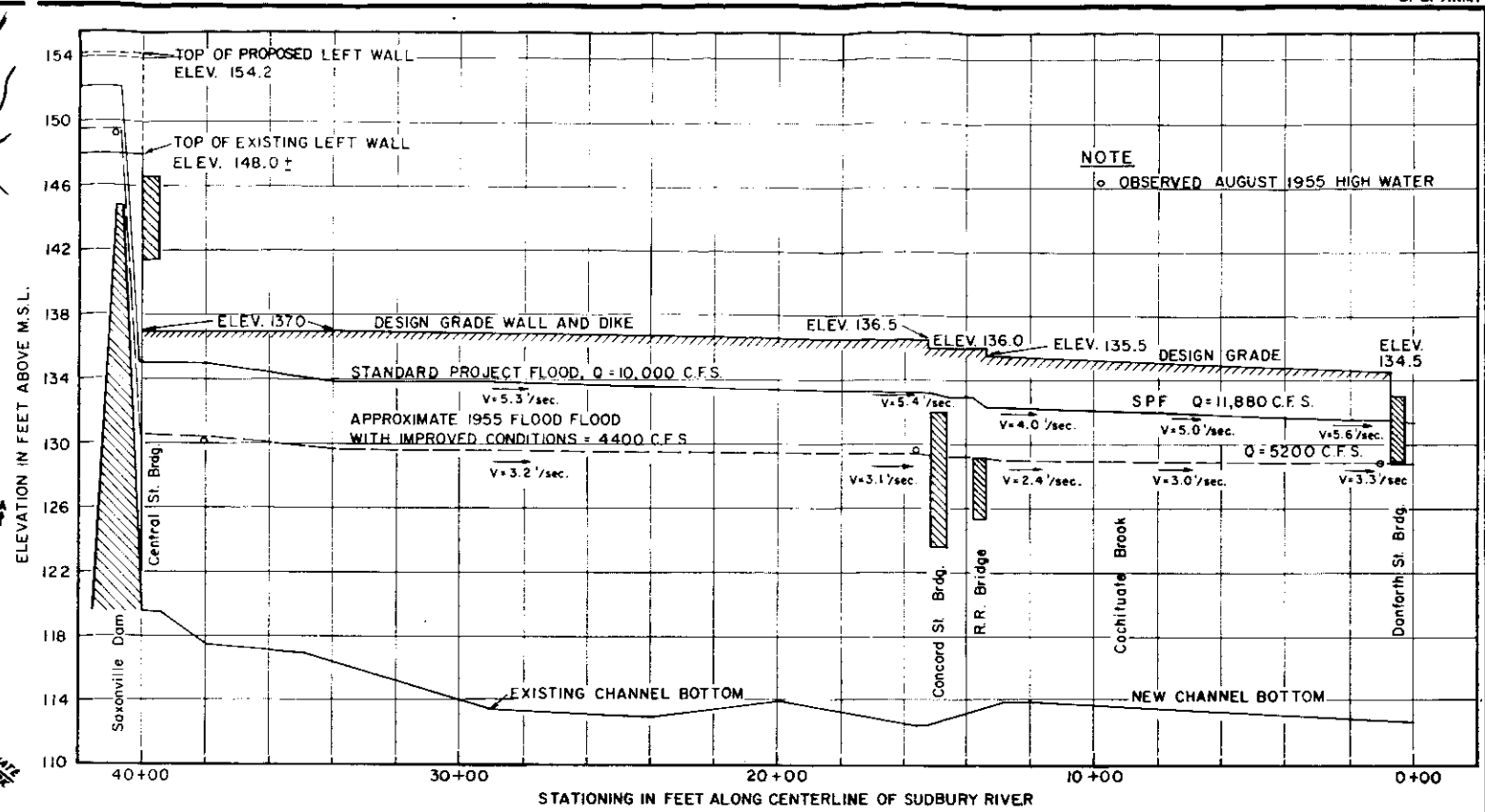
DES. BY	CHK. BY	OK. BY
SUBMITTED		
CHIEF, SECTION		
APPROVAL RECOMMENDED:		
CHIEF, TECHNICAL BRANCH		
REVIEWED:		
PROJECT ENGINEER		
APPROVAL RECOMMENDED:	APPROVED	DATE
CHIEF, BRANCH	CHIEF, ENGINEERING DIVISION	
	SCALE	SPEC. NO.
		DRAWING NUMBER
		SHEET



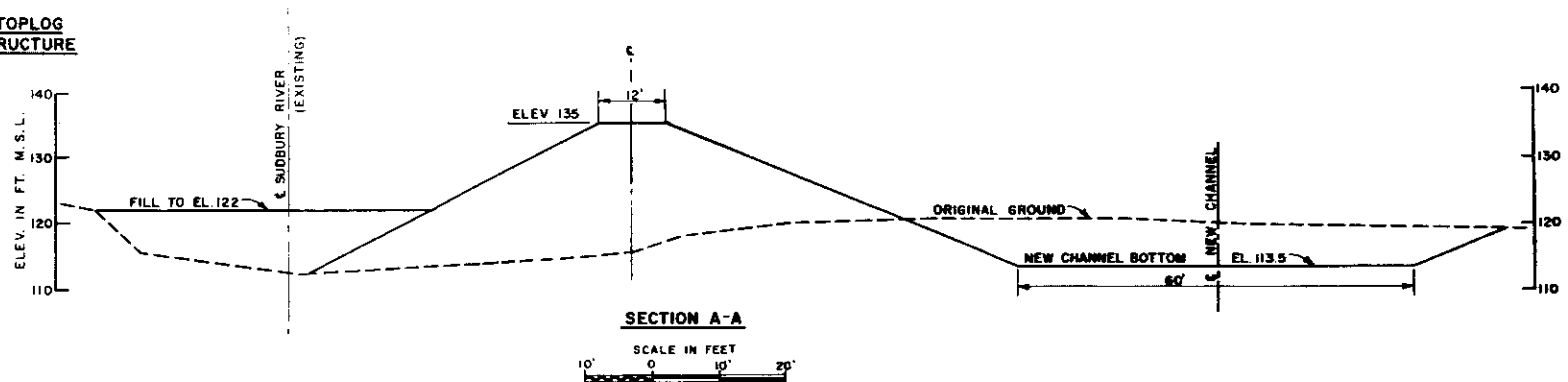
GENERAL PLAN

SCALE IN FEET

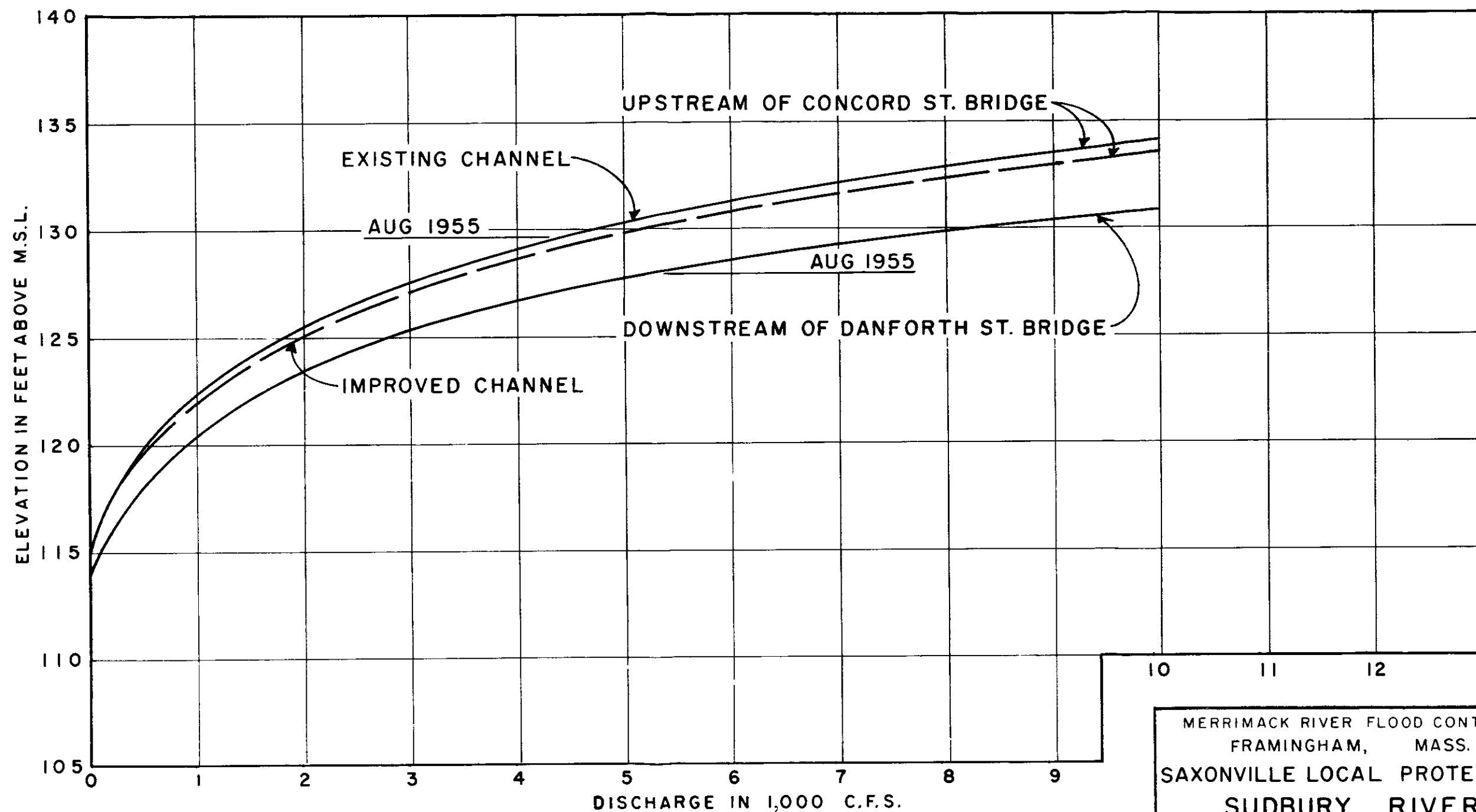
0 100 200



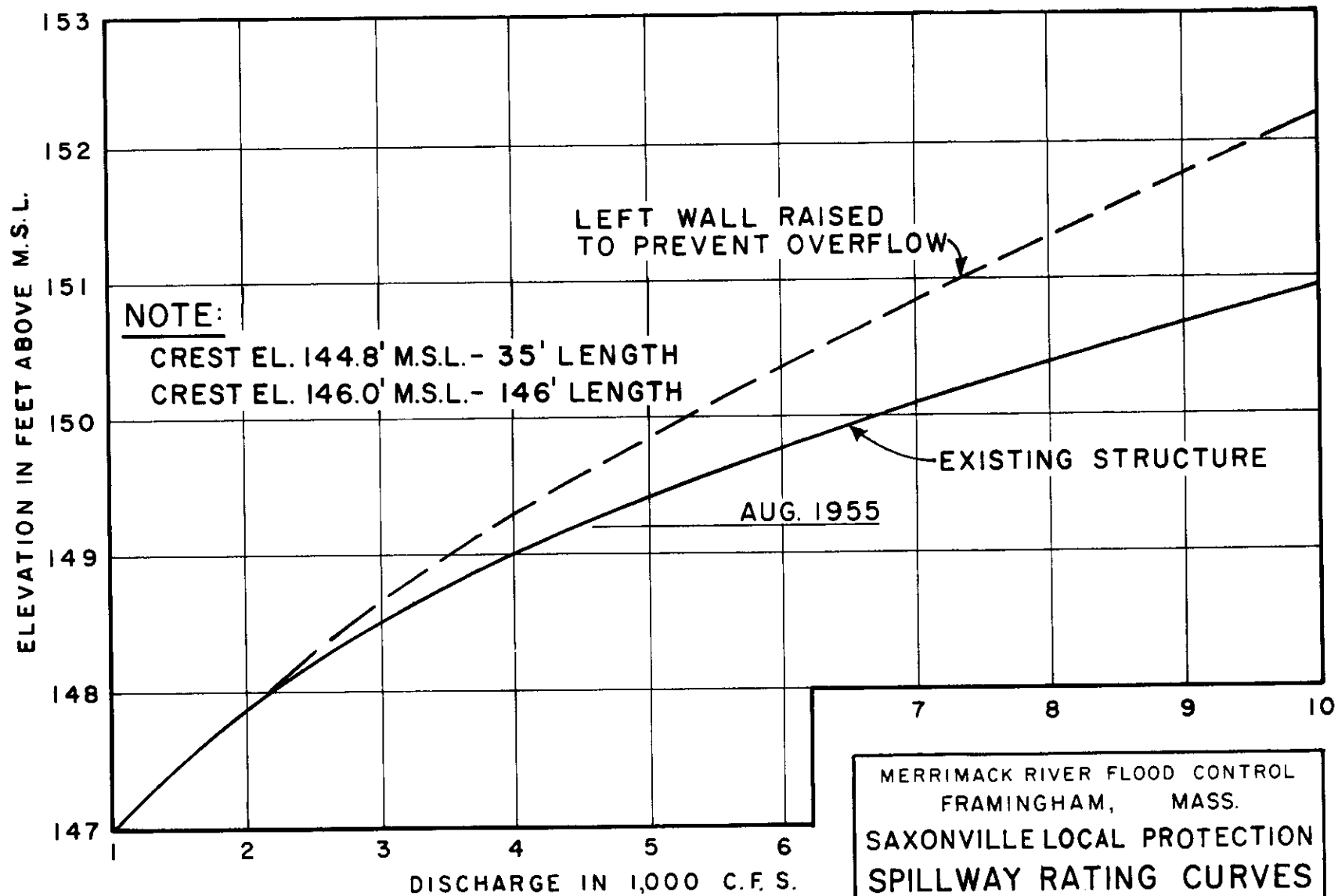
PROFILE OF SUDBURY RIVER AT SAXONVILLE MASSACHUSETTS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
Merrimack, Mass.MERRIMACK RIVER FLOOD CONTROL
FRAMMINGHAM, MASSACHUSETTS
SAXONVILLE LOCAL PROTECTION
PLAN, PROFILE AND SECTION
SUDBURY RIVER MASSACHUSETTS

DR. BY	DR. BY	DR. BY	DR. BY
SUBMITTED			
APPROVED AND FORWARDED		DATE	
SUBMITTED		APPROVED	
CHIEF PLANNING & DESIGN SECTION		CHIEF ENGINEERING SECTION	
SCALE: AS SHOWN		SCALE: AS SHOWN	
DESIGNED BY		CHECKED BY	
DRAWN BY		CHECKED BY	

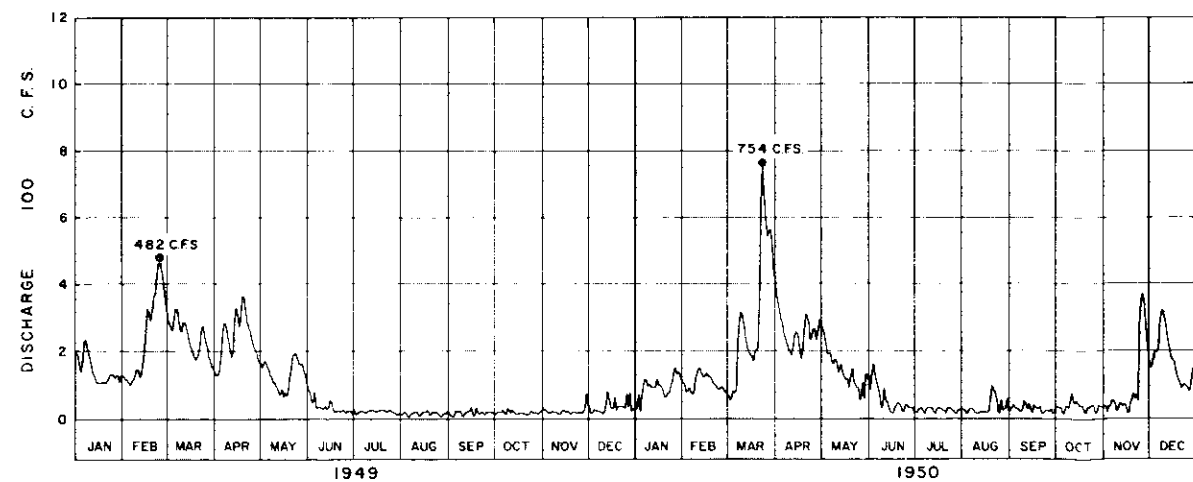
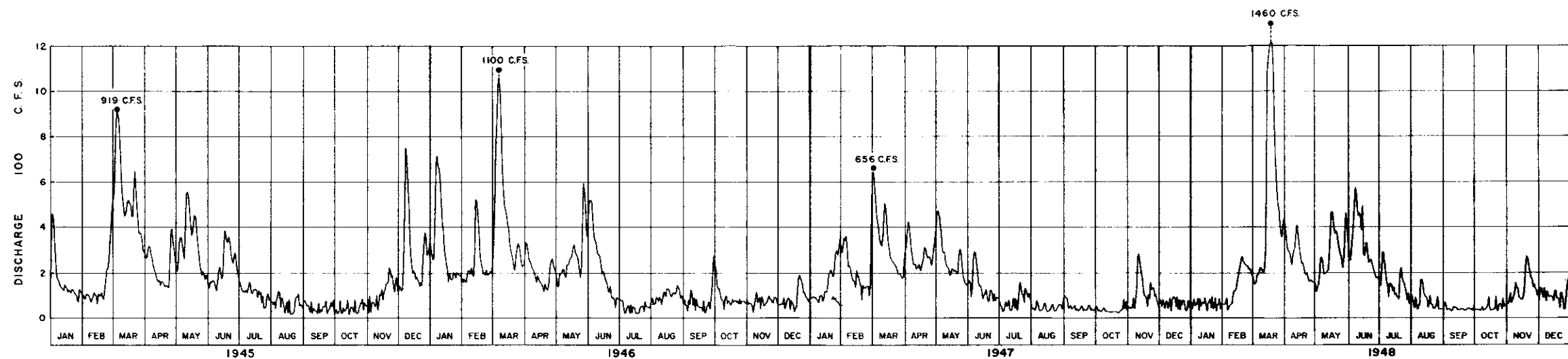
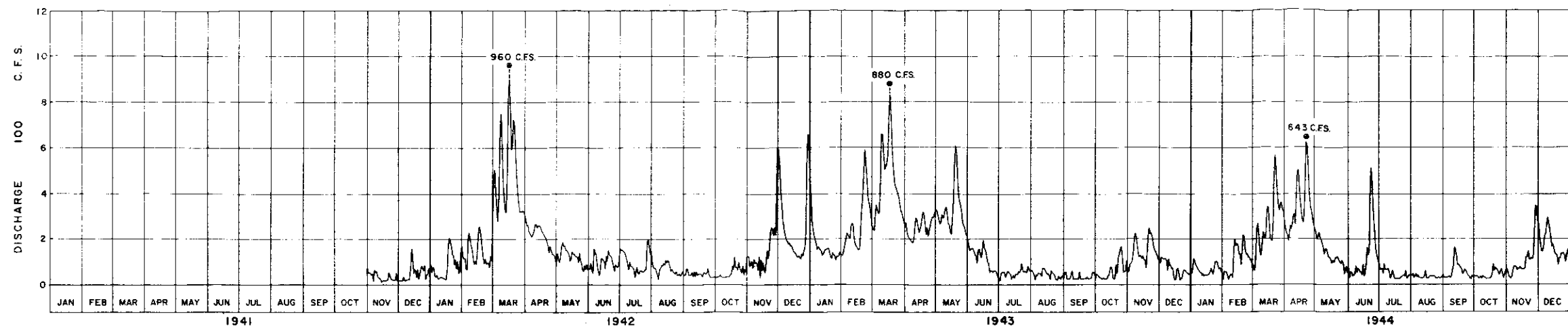


MERRIMACK RIVER FLOOD CONTROL
 FRAMINGHAM, MASS.
 SAXONVILLE LOCAL PROTECTION
 SUDBURY RIVER
 RATING CURVES



MERRIMACK RIVER FLOOD CONTROL
FRAMINGHAM, MASS.
SAXONVILLE LOCAL PROTECTION
SPILLWAY RATING CURVES
SAXONVILLE DAM

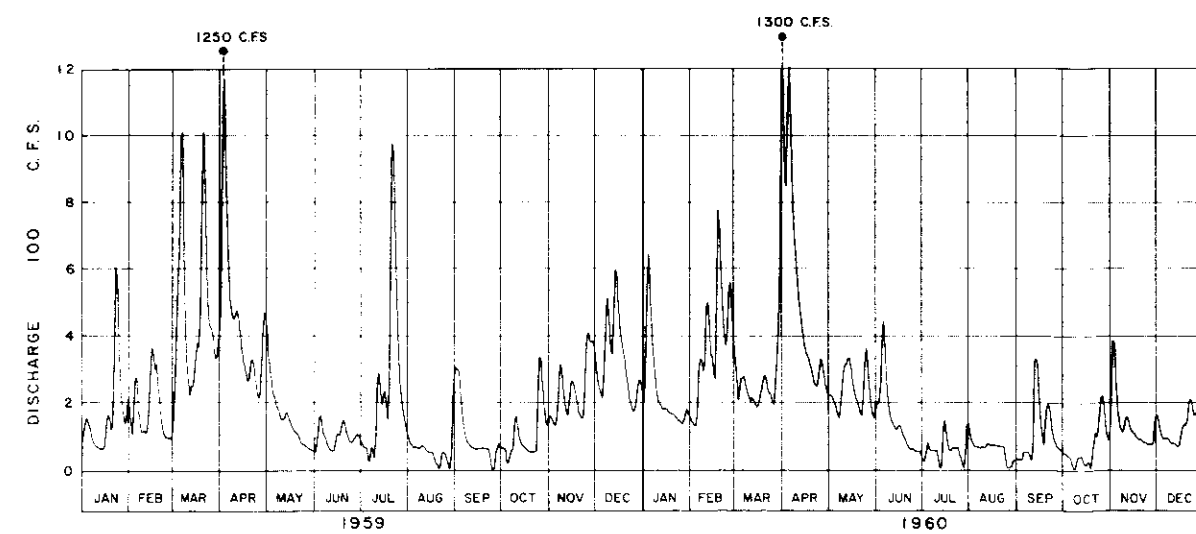
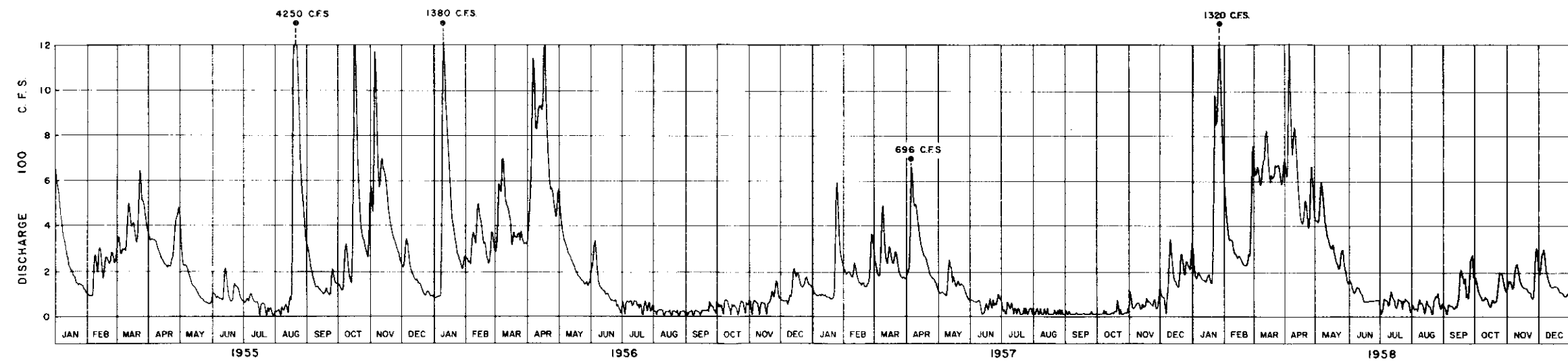
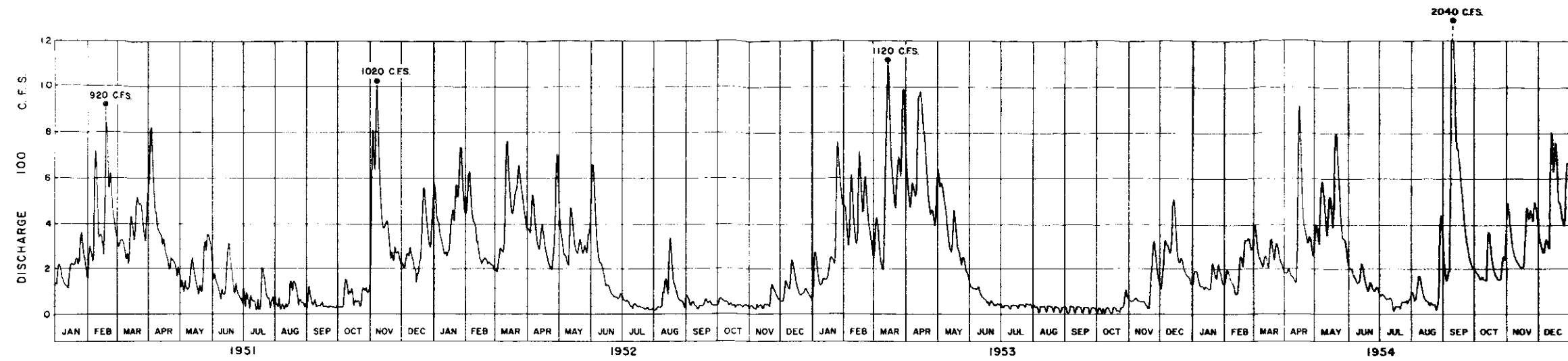
PLATE I-II



NOTES

1. THESE HYDROGRAPHS REPRESENT THE DAILY AVERAGE STREAMFLOW OF THE ASSABET RIVER AT MAYNARD, MASS. THE DRAINAGE AREA OF THE ASSABET RIVER AT MAYNARD IS 116 SQUARE MILES. THE DRAINAGE AREA OF THE SUDBURY RIVER AT SAXONVILLE DAM IS 86 SQUARE MILES.
2. SOME INSTANTANEOUS PEAK DISCHARGES ARE SHOWN BY THE SYMBOL -●-
3. THE DATA CONTAINED HEREON ARE NOT INTENDED AS REPRESENTATIONS OR WARRANTIES BUT ARE FURNISHED AS INFORMATION ONLY. IT IS EXPRESSLY UNDERSTOOD THAT THE GOVERNMENT WILL NOT BE RESPONSIBLE FOR ANY DEDUCTION, INTERPRETATION OR CONCLUSION THEREFROM MADE BY ANY BIDDER OR CONTRACTOR.
4. RATING CURVES FOR THE SUDBURY RIVER AT SAXONVILLE ARE SHOWN ON PLATES 1-10 AND 1-11.

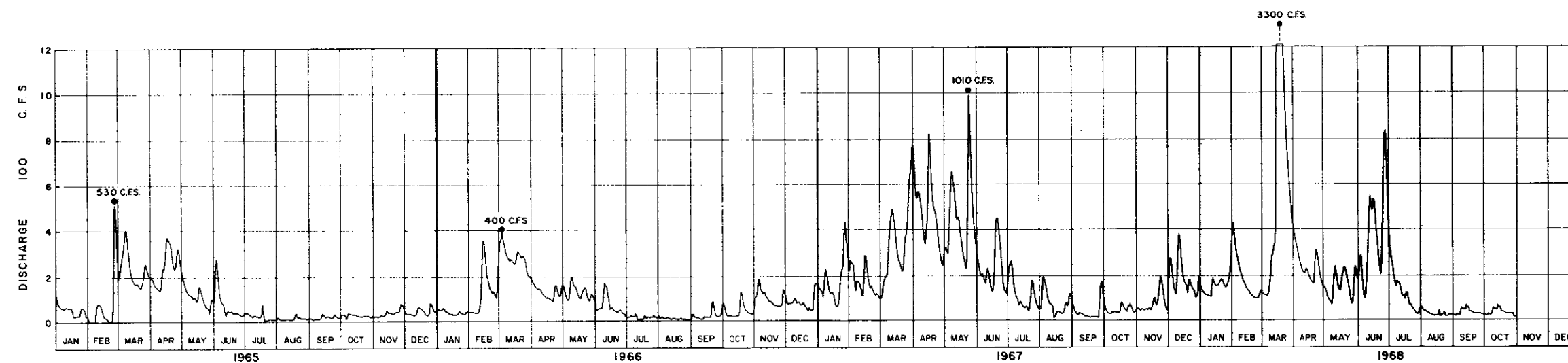
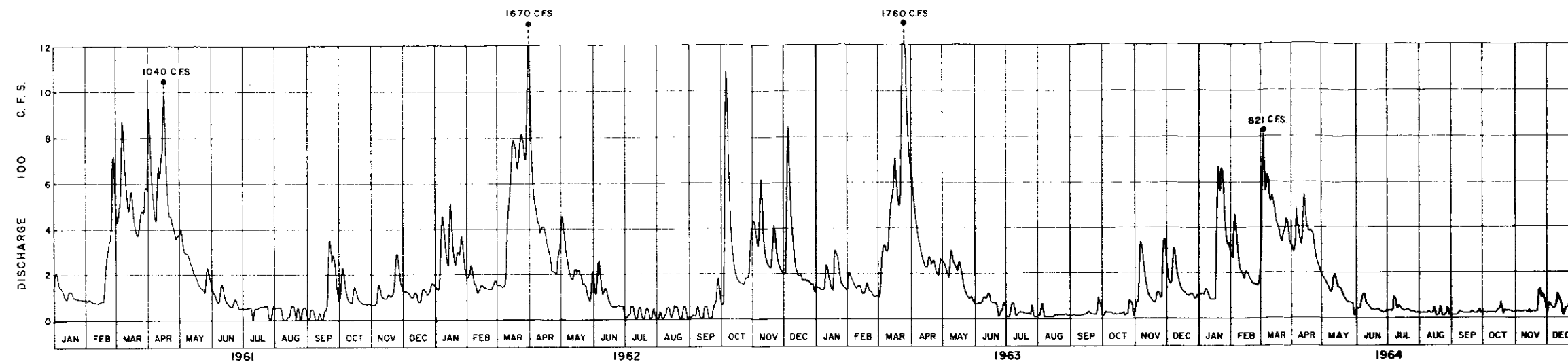
DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.			
MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS			
SAXONVILLE LOCAL PROTECTION HYDROGRAPHS NO. 1			
ASSABET RIVER MASSACHUSETTS			
APPROVED FOR PUBLICATION		DATE	
CHIEF, ENGINEERING SECTION		CHIEF, DRAWING SECTION	
SCALE		SPEC. NO.	
DRAWING NUMBER		SHEET	



NOTE

SEE HYDROGRAPHS NO. 1 FOR NOTES

DEPARTMENT OF THE ARMY NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.		
MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS		
SAXONVILLE LOCAL PROTECTION HYDROGRAPHS NO. 2		
ASSABET RIVER MASSACHUSETTS		
DATE:		
APPROVED		
CHIEF, ENGINEERING DIVISION		
SCALE		
SPEC. NO.		
DRAWING NUMBER		
SHEET		



NOTE
SEE HYDROGRAPHS NO. 1 FOR NOTES

DES. BY SUBMITTER			NEW ENGLAND DIVISION CORPS OF ENGINEERS WALTHAM, MASS.		
DR. BY CHIEF, SECTION			MERRIMACK RIVER FLOOD CONTROL FRAMINGHAM, MASSACHUSETTS		
CH. BY APPROVAL, RECOMMENDATION			SAXONVILLE LOCAL PROTECTION HYDROGRAPHS NO. 3		
REVISIONS: PROJECT ENGINEER			ASSABET RIVER MASSACHUSETTS		
APPROVAL, RECOMMENDATION: CHIEF, BRANCH			APPROVED DATE		
CHIEF, ENGINEERING DIVISION			SCALE SPEC. NO.		
DRAWING NUMBER			SHEET		